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No. 15

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This report contains information on national-level science policies, technology strategies, and research and development programs in West European science and technology in general and specifically in civil technology, with particular attention to transportation, energy, chemical manufacturing, industrial automation and technology transfer. The report will focus primarily on France and the Federal Republic of Germany, but will also cover important developments in Italy, the Netherlands, Sweden and other West European countries.

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FEDERAL REPUBLIC OF GERMANY

RESEARCH, EXPERIENCE IN IMPROVING DISTRICT HEATING

Duesseldorf BRENNSTOFF-WAERME-KRAFT in German No 11,Nov 79 pp 424-429

[Article by K. Jensch and W. Piller: "Block Thermal Power Plant Technology and Its Contribution to Efficient Energy Utilization"]

[Test] In addition to general comments on block thermal power plant technology, this report contains results derived from measurements at the Heidenheim prototype plant. The authors also discuss the multi-motor plant which has in the meantime been installed there.

Block Thermal Power Plant Technology--A Method for Power-Heat Coupling

Shortages and rising prices of conventional primary energy sources as well as dependence on energy-exporting countries increasingly influence economic and political thinking in the FRG. Thus, Federal Research and Technology Minister Hauff said (1): "Within the context of its energy policy, the federal government very clearly gave top priority to economical and efficient energy utilization in order to derive more advantage from the energy sources which are available to us but which are becoming more expensive in the long run--that is to say, more advantage than was possible with the earlier technologies and action programs."

In recent years, this has led to increased efforts in the field of using alternate energy sources, reducing energy consumption, as well as employing new techniques for the better utilization of primary and terminal energy. These industrial systems among other things include plants which operate according to the power-heat coupling principle and which primarily serve for the simultaneous generation of current and heat.

In fossil-fired thermal power plants with long-distance heat uncoupling, we mostly find steam turbines which are being operated according to the counterpressure, tapping-condensation, or bleeding-condensation principle. In.the peak-load thermal power plants, high-capacity thermal power plants are also used. For industrial and economic reasons, the capacity range of these thermal power plants is generally upward of 30 Mw. As a result of that, the utilization area of the uncoupled long-distance heat systems must be confined to larger regions with a high heating density (2). The topics connected with this technology were covered comprehensively in two studies prepared for the BMFT (Federal Ministry of Research and Technology] (2, 3). Both from the viewpoint of technology and from the angle of the field of application however one cannot simply transfer these discoveries to the block thermal power plants. Their utilization is aimed at supplying smaller facilities and facility groups, whereby they are installed near the consumer. The output spectrum, as far as we know today, would seem to extend up to about 5 Mw, which corresponds to a thermal output of about 7.5 Mw (4, 5). When it comes to providing a lower output limit, we must wait for the current development of plants with series-passenger-car motors in the middle [weight] class (6).

Block thermal power plants operate according to the power-heat coupling principle. A plant here can consist of one or more units, whereby the generator, for each unit, is driven by a heat motor [thermal power machine]. Basically, one could use both steam-power and combustion-power machines in the order of magnitude determined by the ultimate objective--specifically, in both cases, both fluid-flow engines and piston engines. Earlier investigations however showed that, for plants in this capacity range, steam turbines and steam motors are less suitable, provided we do not demand steam for processing purposes (4).

This is why the concept of BHKW (block thermal power plant) in public discussion and literature is confined to plants in which we use combustion motors (internal-reciprocating combustion motor, diesel motor) or gas turbines as the drive machines. Here one can use not only liquid but also gaseous fuels.

The basic heat circuits for these subsystems are shown in Figure 1 (4). While, in the case of gas turbine plants, the useful thermal energy comes out exclusively in the form of waste gas heat, we find that the waste heat from combustion motors is made up of waste gas heat and cooling-water heat. In gas turbines, the waste gas heat can be used in a waste heat boiler on the basis of the high temperature levels (350-550°C) for steam or hot-water supply. In combustion motors and in a series connection of cooling-water heat exchanger and waste heat boiler--as shown in Figure 1a--we have the attainable hot-water temperature given in advance by the cooling-water temperature or by the possible hot-water temperature at the output of the cooling-water heat exchanger and by the shares of cooling-water heat and usable waste gas heat out of the total heat generation volume. In case of a corresponding circuit diagram, we can thus attain temperatures of about 100°C and when we use high-temperature liquid-cooling [evaporation cooling], we can get more than 100°C (110-120°C) (4). Basically, one can offer hot water or steam also when the heat exchanger circuits are separated--motor cooling water and waste gas.

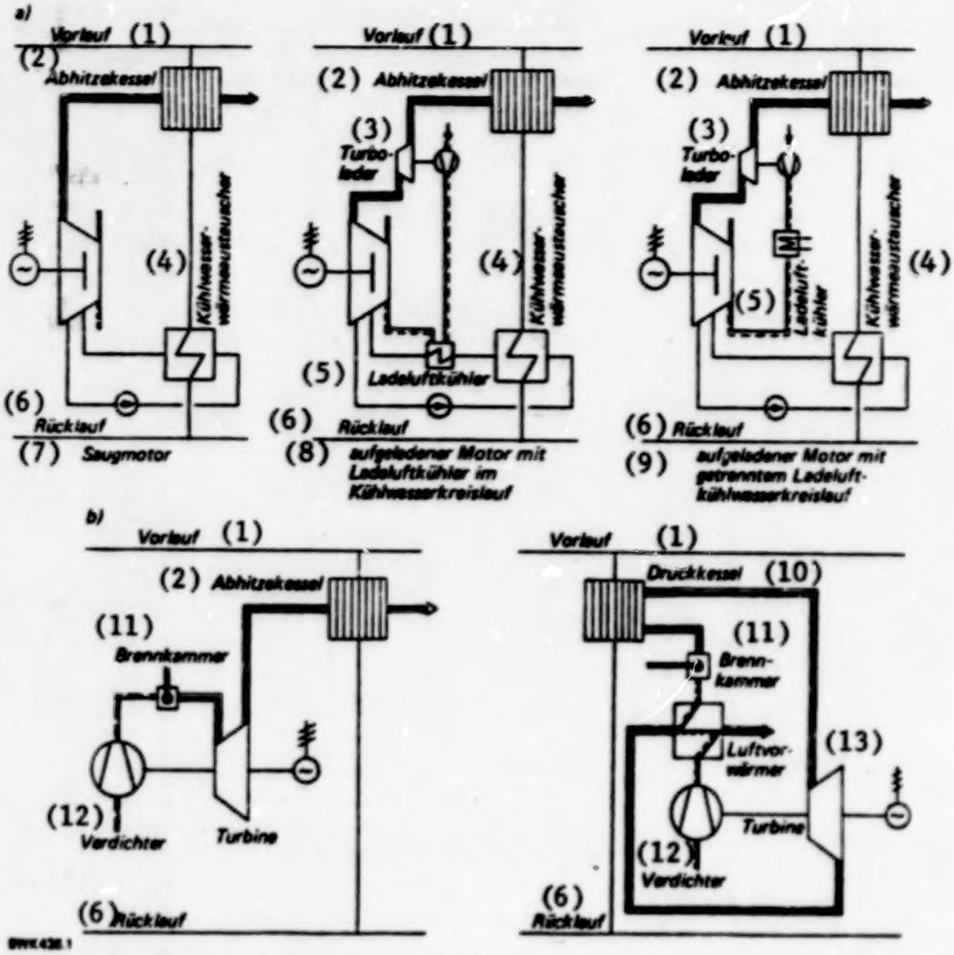

Bild 1: Wärmeschaltbilder von BHKW-Aggregaten
a Diesel- bzw. Ottomotoren *b* Gasturbinen

Figure 1. Heat circuit diagrams for BHKW subsystems.

Key: a--Diesel or internal-reciprocating combustion motors; b--Gas turbines; 1--Lead-in run; 2--Waste heat boiler; 3--Turbo-charger; 4--Cooling water heat exchanger; 5--Charge air cooler; 6--Return run; 7--Suction motor; 8--Supercharged motor with charge air cooler in cooling water cycle; 9--Supercharged motor with separated cooling air-cooling water cycle; 10--Pressure boiler; 11--Combustion chamber; 12--Condenser; 13--Air preheater.

Because of its industrial and financial conditions, as we can see in Table 1 (7), the BHKW is rather easily integrated into small long-distance heat supply islands and can contribute to the gradual buildup of larger long-distance heat supply networks.

Table 1. Comparison between Various Long-Distance Heat Generation Plants

	Block thermal power plant	Thermal power plant	Thermal plant
Required heat load density	As of about 150 kw/km^2 for focal-point consumers	As of approximately 30 Mw/km^2	As of approximately 15 Mw/km^2
Approximate surface area requirement	$\geqq 30$ m^2	$\geqq 25{,}000$ m^2	$\geqq 500$ m^2
Distance to nearest residential development of building	$\geqq 0$ m	$\geqq 200$ m	$\geqq 100$ m
Time limit for erection of heat consumers	Any	<3a	<5a
Preliminary financial expenditures	Little or none	High	Medium

The individual components must be designed according to two criteria. At first we should in the optimum possible fashion adjust both to the heat requirement and to the current requirement of the consumers. This is done through a suitable capacity selection for the individual components. On top of that we have the requirement for being able to keep up with the capacity curve of the consumers at any time--and this at least involves the thermal capacity curve. Here we have several variations which however must always be based on the operating mode selected for the motor-generator block. Any heat requirement beyond the head contribution generated by the motor-generator block must be capable of being covered by other system components.

There are two basic ways in which a combustion motor can be operated. First of all, it can be operated in an output-regulated manner; then of course it could also be operated in a certain timed fashion with a fixed and constant load point whereby the maximum deliverable output of the central unit here helped determine the duration of consumption-dependent operating intervals.

For a complete evaluation of the BHKW technology one must also look at the way it fits into the already existing remaining supply structure. While the effects of BHKW operation entail only minor problems for long-distance heat supply, we have a series of industrial and economic questions which have as yet not been answered in case of parallel operation with the superordinate electrical grid. First of all, the economy of these plants primarily depends on the evaluation of the sales proceeds from the electrical current generated. Besides, the network stability (voltage and frequency constancy) of the superordinate network must not in any way be impaired by the utilization of BHKW, which means that we must have a relatively high control and regulating expenditure which must be extensively independent of the plant output. That expenditure is influenced by the question of blank-output exchange whereby we must differentiate whether we use synchronous or asynchronous generators in the central unit. Asynchronous generators in this capacity category are specifically cheaper and require only simple regulation but they do need blank current for magnetization from the superordinate grid. In the case of the synchronous machines, which are more expensive in terms of regulation technology, there is a possibility of employment in island, emergency-current, or phase-shift operation via DC excitation.

Certain references to the technical cooperation of individual components for BHKW technology can also be obtained from the total-energy plants which have been placed in operation in the United States for about 15 years. To be sure, these plants in some cases are very much more simple in engineering terms and they mostly operate according to the island system. To that extent, the lessons learned there can be transferred only to a limited extent to those plants which must meet the above-mentioned requirements during parallel operation with the public grid.

In order to gain practical experience on the utilization of block thermal power plants under European conditions, the first experimental plant was built in Heidenheim in 1976. It was promoted by the BMFT under the title "Planning, Erection, and Operation of a Block Thermal Power Plant" (8). The conclusive results from the measurement investigation of the energy operations performance will be described in the following chapter in terms of supplementation and correction of (9).

Energy Operation Performance of Central Unit in Single-Motor Plant

The originally anticipated supply region for the block thermal power plant encompasses 283 residential units in 15 three-five-story apartment complexes. The entire residential surface area to be heated comes to 16,760 m^2 and the designed heat requirement here is 1.76 Mw.

The design was based on the heat requirement, whereby the thermal output of the motor-generator block--hereafter called the central unit--was determined to meet 50% of the designed heat requirement. Any heat requirement beyond that or a low thermal load in the summer was to be supplied, as desired, by a natural-gas-fired peak-load boiler or by electrical continuous-flow heaters; a hot-water tank was provided to balance out any short-term requirement fluctuations.

The nominal output of the synchronous generator used came to 800 kva with a cos ϕ of 0.8. A feed-in station, going into the network of the Heidenheim city works, was erected for the generated current.

The heat distribution network of the block thermal power plant can be connected, via a tapline, with a second network whose consumers are identically structured which reveals a designed heat requirement of about 2.4 Mw. To supply this part of the development, there is a central heating plant with two gas-fired boilers with a total capacity of 2.8 Mw.

The possibility of connecting both nets in parallel in practice leads to a situation where--apart from times when special experiments are conducted--the BHKW, in case of a low heat requirement, supplies both development parts with heat from the central unit while the peak load requirement is met, in case of a heavier load, extensively by the boilers of the second central heating plant.

The basic idea behind the energy measurements was, in a compact recording space, to record all energy flows which exceed the balance limits as well as their breakdown within the recording space, in order thus to be able to come up with a compact energy balance sheet. Here, the original supply area of the 283 residential units and the pertinent block thermal power plant were used as basis for the balance-sheet space [interval]. Since this involved an existing long-distance-supplied residential area, the recording of the electric energy requirement for that same residential area required the erection of a long-distance transmission system from all of the individual component buildings.

The results of these measurements were described in (9); of course, corrections had to be made since then on various measurement values. This was due to the fact that there was an error inherent in the necessary heat volume measurements and that error could not be cleared up with the customary tolerance limits in the measurement instruments which the manufacturer likewise tested several times. This need did not emerge until toward the end of the period of experimentation, when the plant operator also ran the originally much earlier planned experimental programs for the system components of peak-load boiler and continuous-flow heater which are extensively known in energy terms.

Because of the early and unpredictable total damage to the combustion power machine, the planned repetition of the various series of experients could no longer be accomplished after a renewed adjustment of the measurement instruments to the real situation at the plant. But because the energy conditions of the tecnically traditional plant components--such as the peak-load boilder and the electrical continuous-flow heater--are well known, one may consider the experimental results described below as being representative because they [the components] were used for the correction of the heat volume measurements.

During the motor experiments, the combustion engine was operated during various load conditions and various outside temperatures extensively in the stationary state in order to get the characteristic energy curves. In addition to the initial or terminal point of the characteristic curve (idling or full load), load points were given as standard values at 25%, 50%, and 75% of the nominal electrical capacity, by way of load states.

A regression calculation was performed in order quantitatively to express the connection between the sum of the electrical capacity [output] (P_{el}) and the heat output from cooling water ($P_{\text{th, cooling water}}$). Here we used a quadratic setup which led to the following result deviating from the one given in (9):

$$
\begin{aligned}
&P_{el} + P_{\text{th, Kühlw}} = \\
&= 246 + 1{,}56 \cdot P_{el} + 0{,}00004 \cdot P_{el}^2, \text{ in kW}
\end{aligned}
$$

Kuehlw.--cooling water.

The corresponding regression equation for the entire useful output came to the following:

$$
\begin{aligned}
&P_{el} + P_{\text{th, gesamt}} = \\
&= 315 + 1{,}96 \cdot P_{el} + 0{,}00016 \cdot P_{el}^2, \text{ in kW}
\end{aligned}
$$

Gesant--totals.

And the one for gas utilization came out as follows:

$$P_{Gas} = 423 + 2{,}37 \cdot P_{el} + 0{,}00056 \cdot P_{el}^2, \text{ in kW}$$

The regression equations here have in common a degree of certainty of more than 99% and they also share the fact that the quadratic member is relatively small compared to the linear share which in fact signifies the approach to a straight line.

We can furthermore tell from the extremely close connection here that the characteristic curves--which after all are made up of the totality of the experimental series--do not undergo any change along with the variation in the outside temperature.

From Figure 2, which can be drawn with the help of the relationships described, we can see that the electrical efficiency reaches its maximum of just about 30% at full load. At half-load it drops by about 5 points to 25% in order then, as the load is further reduced, to decline progressively toward zero. This would mean, for purely current-oriented plant utilization, that, as of one-half of the load range, about 83% of the maximum efficiency are already reached and that the second half of the load range could be used for an output-regulated operation without too much loss in efficiency.

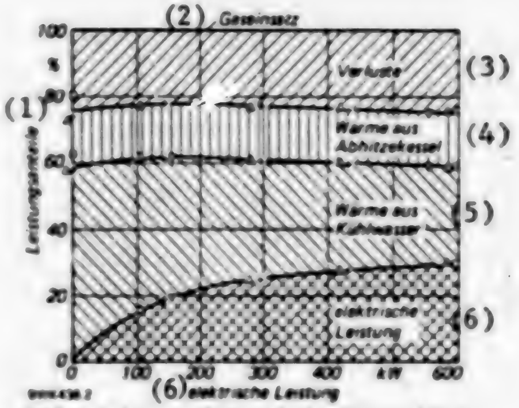

Bild 2: Leistungsaufteilung in der Zentraleinheit

– 5 °C △ + 15 °C

◆ + 5 °C ▽ + 25 °C

Gaseinsatz ≙ 100%

Figure 2. Output distribution in central unit.

Key: 1--Output shares; 2--Gas utilization; 3--Losses; 4--Heat from waste heat boiler; 5--Heat from cooling water; 6--Electrical output; gas utilization = 100%.

But if in addition to current generation we also look at the heat yield, which certainly makes sense here, in other words, if we base our considerations also on the overall efficiency, then the operating procedure optimization looks meaningful in a different way. Here we find, starting with an efficiency of about 75% while idling, a maximum of 78% at about 1/4 load and we furthermore find an almost linear decline of the efficiency down to about 75% at nominal load. In spite of this tendency, operation in the lower load range of course makes little sense because it is economically unjustifiable to operate a plant, which is so cost-intensive, as an "expensive heating furnace," particularly since "current" energy must be evaluated higher both energetically and economically. From this we can conclude that, in case of the regulated utilization of the central unit in single-motor plants, we would have to try to get into the upper load range between about 3/4 load and full load as the regulating range.

We get the following for the percentage load subdivision at the nominal point of the central unit:

Gas utilization		100%
Electrical energy		29%
Heat from cooling water	29%	
Heat from waste heat boiler	17%	
Heat, total		46%
Losses		25%

Figure 2 furthermore tells us that heat generation from waste heat boilers remains percentagewise constant over the entire load range when measured by the gas utilization. On the other hand, the share of the heat input from cooling water declines as the electrical load increases. This behavior is to be traced back to the fact that the heat transfer in the waste heat boilers is extensively determined by convection whereby primarily the mass flow of flue gas and its temperature constitute parameters for the usable heat volume. On the other hand, in motor block cooling, heat transfer takes place within the cylinder of the combustion engine from the working medium to the cylinder wall and thus into the cooling water increasingly due to radiation. In this kind of heat transfer, only the temperatures or their differences play a role and the mass flow does not have any bearing.

The characteristic current value is an important electrical industry magnitude. It is the ratio of electrical energy generation to heating heat generation in coupled power-heat generation processes. The characteristic current value permits a simple comparison amoung the various current-heat generating plants. For the subsystem we are looking at here, therefore, Figure 3 shows the curve of the characteristic current value plotted against the electric power output. For the unit's nominal point it attains a value of about 175 kw/GJ and is thus certainly in an order of magnitude which, in a customary power-heat coupling setup, is attained with a steam turbine in counterpressure operation when there is a requirement for identical long-distance heat network lead-in temperatures, in other words, 80-90°C as in the case at hand. Regarding the characteristic current value and the efficiency of current generation, this plant is roughly comparable to gas/steam turbine plants.

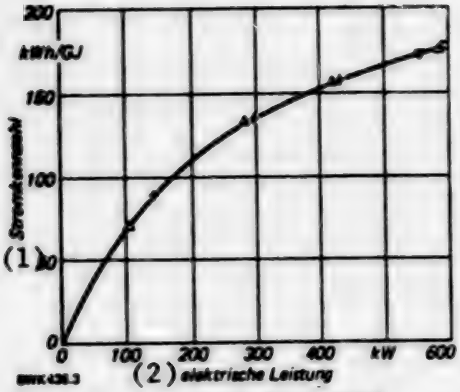

Bild 3: Stromkennzahl der Zentraleinheit

□ – 5 °C △ +15 °C

+ + 5 °C ▽ +25 °C

Figure 3. Characteristic current value of the central unit.

Key: 1--Characteristic current value; 2--Electric power output.

Usual Manner of Operating Prototype Plants

During times when no special experiments were conducted with the plant, the block thermal power plant was run according to a method determined by the operator, the "Heidenheim operating program" described below. The essential aspect of this program consisted in using the central unit with maximum electric output in any case during the current accounting and computing time and, parallel to that, covering the heat requirement of the consumers at any moment. Moverover, an attempt was made to achieve the highest possible utilization of the central unit, an effort which was supported by the fact that, during thermal low-load times, the long-distance heat network of the second supply region was serviced from the block thermal power plant. As a result, it was possible to run the central unit--which was being used by the plant operator only in terms of on-off operation at nominal load--for a relatively long time on nominal operation whereas the rest of the time it was shut down.

The operating procedure described here is reflected in Figure 4 where the plant's output phases are shown for a day with an average outside temperature of 13.5°C. On that day, only the central unit was in operation in order, by itself, to supply both parts of the residential development with heat. Figure 4 shows the requirement of the original settlement area for the current as well as the generation volume in the BHKW. Grid feed and generation are shown for heat.

The accounting and computing time of the Heidenheim city network, specified by the supraregional current supplier, came during the time between 0800 and 1200; this is why an attempt was made to operate the central unit as continually as possible during the morning hours. But since this is possible only if the resultant heat is also accepted by the consumer or can be stored, the plant operator made sure that the existing tank was capable of absorbing this volume. With a tank volume of 50 m^3, it was possible to store an average of 1,000 kwh in this storage facility, which means that the running time of the central unit could be extended by about 1 hour. In addition, it was possible to support this storage effect by utilizing the storage capacity of the long-distance heat network.

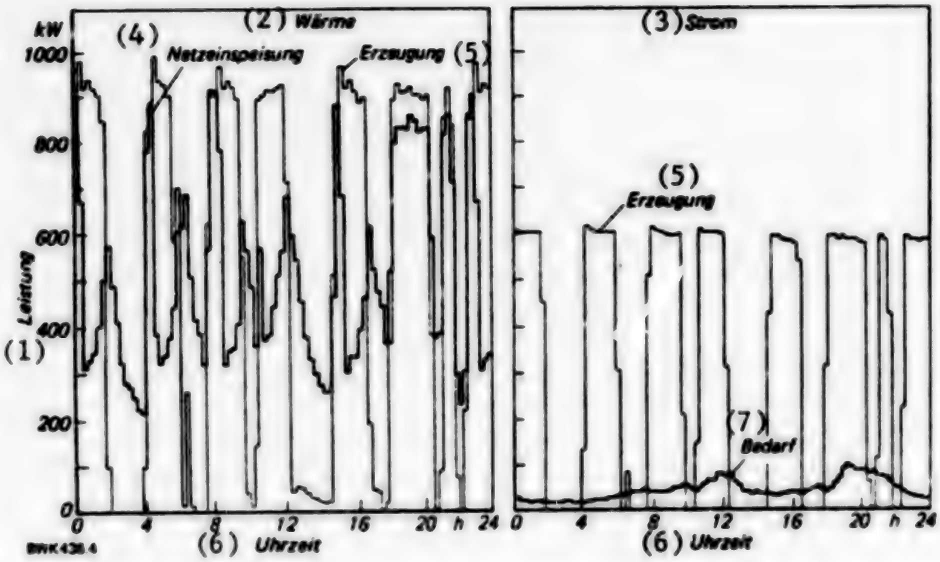

Figure 4. Output curve on one day during transition time.

Key: 1--Output; 2--Heat; 3--Current; 4--Grid feed; 5--Generation; 6--Clock time; 7--Requirement; h--hours [clock time].

Characteristic Values for Energy Performance

In 1977, the central unit achieved a total operating time T_b of 5,790 hours. In the process, 3,195,800 kwh of electrical energy were generated. The maximum value for electrical quarter-hour output came to 630.4 kw.

These two values give us the annual utilization time of the central unit for current generation at:

$T_{m,\ el}$ = 5,070 hours per year

If we relate the utilization time to the total number of hours throughout the year, we get the utilization factor. In 1977, it gave us the following figure for the motor-generator block:

n_{el} = 0.579.

The corresponding values for heat supply are as follows with a generated annual energy volume of 5,166,561 kwh and a maximum thermal hourly output of 986.7 kw:

$T_{m,\ th}$ = 5,236 hours per year

n_{th} = 0.598.

These values are rather high and this is above all due to the previously explained operating procedure where an additional supply region was supplied from the block thermal power plant during thermal low-load time. This region is about twice as big as the original supply region which means that in the summer it was possible to deliver about double the heat energy from the central unit.

A brief and rough calculation is intended to show what effects the raising of the summertime load by a factor of 2 will have due to the parallel connection of the second consumer region when it comes to the utilization time of the thermal maximum output of the central unit.

If we start with the idea that the residential development, of the kind we find in the supply region of the block thermal power plant, as a rule reveals an annual utilization time for the mathematical designed heat requirements amounting to about 1,800 hours and if we assume that a plant--which can handle a 50% output base, measured by the mathematical designed heat requirement--generates about 80% of the annual heat requirement, then we get about 3,100 annual full-scale utilization hours for this plant; considering the grid losses, we get figures of around 3,400 hours per year.

From these data we can tell that the selective parallel connection of the two supply regions made it possible to increase the actually achieved utilization time about 1.5 times.

The difference in the utilization time of current and heat generation can be explained here by saying that, out of the 5,790 operating hours of the central unit, about 346 hours had to be set aside for start-up and shutdown procedures during which the subsystem did not provide any electrical energy although it did supply thermal energy from idling operations.

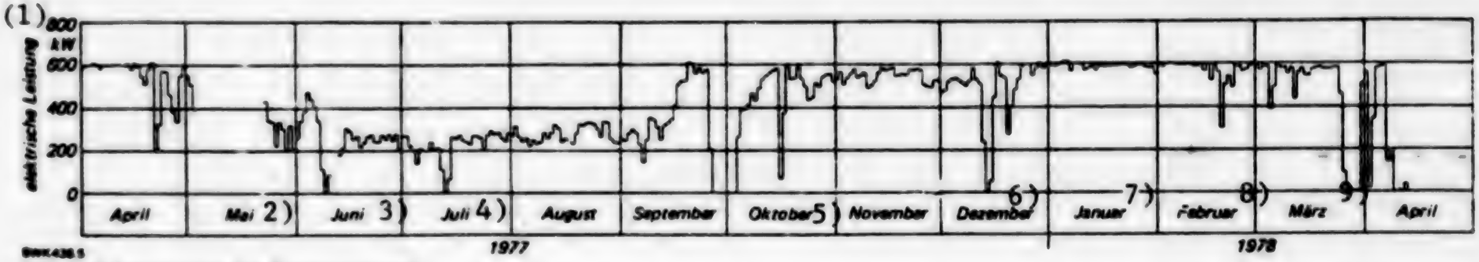

Bild 5: Leistungsgang der Stromerzeugung

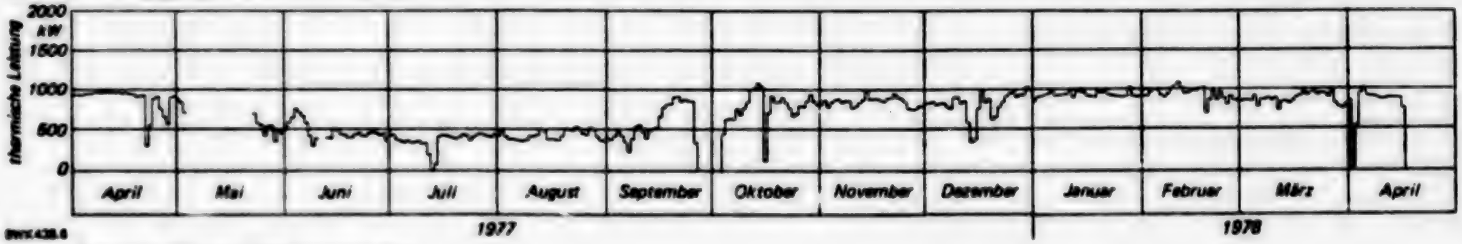

Bild 6: Leistungsgang der Wärmeerzeugung

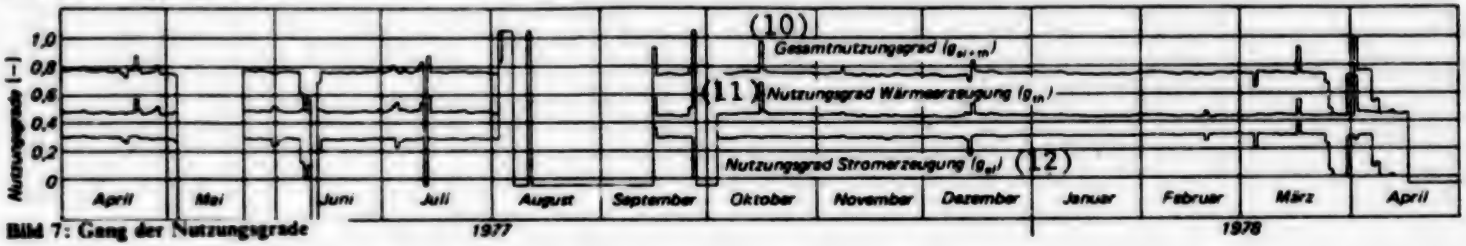

Bild 7: Gang der Nutzungsgrade

Figure 5. Current generation output curve. Key: 1--Electric power output; 2--May; 3--June; 4--July; 5--October; 6--December; 7--January; 8--February; 9--March.

Figure 6. Heat generation output curve. Key: 1--Thermal output; 2--May; 3--June; 4--July; 5--October; 6--December; 7--January; 8--February; 9--March.

Figure 7. Utilization intensity curve. Key: 1--Utilization intensiy; 2--May; 3--June; 4--July; 5--October; 6--December; 7--January; 8--February; 9--March; 10--Overall utilization intensity; 11--Heat generation utilization intensity; 12--Current generation utilization intensity.

Figures 5 and 6 show the annual output curve for the central unit in terms of current and heat generation, made up of the particular figures for the average daily output. Both output curves reveal a strict dependence on each other, something which can be explained by the rigid coupling of current and heat generation in the motor-generator block.

Earlier we said that the central unit as a rule was operated on a timed basis on "nominal load" and "off." By shifting the durations of the "on" and "off" times during timed operation, it was thus possible to adapt the heat generation to the heat requirements. The average electric output figure during "on operation" can be determined in the following manner: out of the 5,790 operating hours for the central unit in 1977, 346 hours are accounted for by start-up and shut-down procedures; that leaves 5,444 hours during which the generator was connected into the grid. Together with the generated electric energy of 3,195,800 kwh, we thus get the average electric power output of 587 kw.

That corresponds roughly to 93% of the maximum quarter-hour output achieved. This deviation from the nominal or standard point can be explained by the way the plant is regulated and by nonstationary states which might arise.

The average heat generation output can be computed in a similar manner. The numerical figure is 892 kw, corresponding to 90.4% of the maximum output achieved.

The difference in the percentage figures for the electrical and thermal load averages resides in the fact that, proportionately speaking, there is more idling output in connection with heat generation.

The utilization intensities of the central unit, which are in the vicinity of the stationary efficiency, result from these high average generation output figures. Figure 7 shows the average daily utilization intensity of current generation, heat generation, and the daily overall utilization intensity of the plant for 1977 or 1978. In this connection, mathematically undefined values--and that also includes the quotient which develops when the plant is at a standstill--were placed below the zero line in the EDP program. Values in excess of one--which might be caused by the plant's storage performance--are expressed above the 1.0-line without consideration of the actual value. We thus find an almost constant curve for the utilization intensity in terms of current generation throughout the year; the value for heat generation drops by about 2 percentage points after almost constant performance at the start of autumn but then, during the remaining measurement interval, again remains roughly equally large.

The annual utilization intensities, formed by the division of the corresponding annual energy volumes, are similar to the magnitudes we can read off in the figure. They are as follows:

29% for the electrical annual utilization intensity, 46.8% for the thermal annual utilization intensity and

75.8% for the total annual utilization intensity.

Conclusions from Findings So Far: Multi-Motor Technology

The block thermal power plant with combustion engines--which is advantageous in an above-average fashion particularly in the smaller output categories both in terms of electrical efficiency and overall efficiency--represents a meaningful supplementation for coupled power-heat generation whereby however the multi-motor technology, which can be better graduated on the heat and current sides, offers a more meaningful alternative for the future as against the single-motor plants described. This can be recognized from the experimental results but also on the basis of the operational experience gained in the meantime with the 38 small plants--including clear-gas plants --of the most varied design (4).

The multi-motor plants reveal numerous additional advantages. Because of the subdivision over smaller subsystems, one can use modified series-produced engines from truck-engine production as a result of which the cost levels for such plants can be lowered. Moreover, the use of between three and eight motors enables us to achieve a very high availability level and a secured output. This has a decisive effect on the necessary reserve, on economy studies, and on the evaluation of the electric current generated. To be sure, looking at it from the present-day viewpoint, we do not have much long-term experience with modified series-produced motors in BHKW operation but it is certain that, in the multi-motor technology, the individual subsystem can be operated at its best point, something which definitely brings advantages, as compared to load-regulated single-motor plants, both in terms of the efficiency and thus also in terms of the energy performance as well as with respect to emission performance. Besides, simple on-off operation reduces the regulating expenditure and the lifetime is probably also influenced favorably.

One interesting possibility of quantitatively increasing our knowledge-- on multi-motor technology--in addition to these purely qualitative data, again came up in Heidenheim. A new system had to be built in because of the previously mentioned damage to the motor of the previously installed single-motor plant. It was decided to put in a six-motor plant which, in terms of the overall thermal output, corresponds to the old plant. Regarding current generation, asynchronous generators are used, in contrast to the prototype described. Figure 8 shows the circuit diagram for this new plant which has been in operation since December 1978.

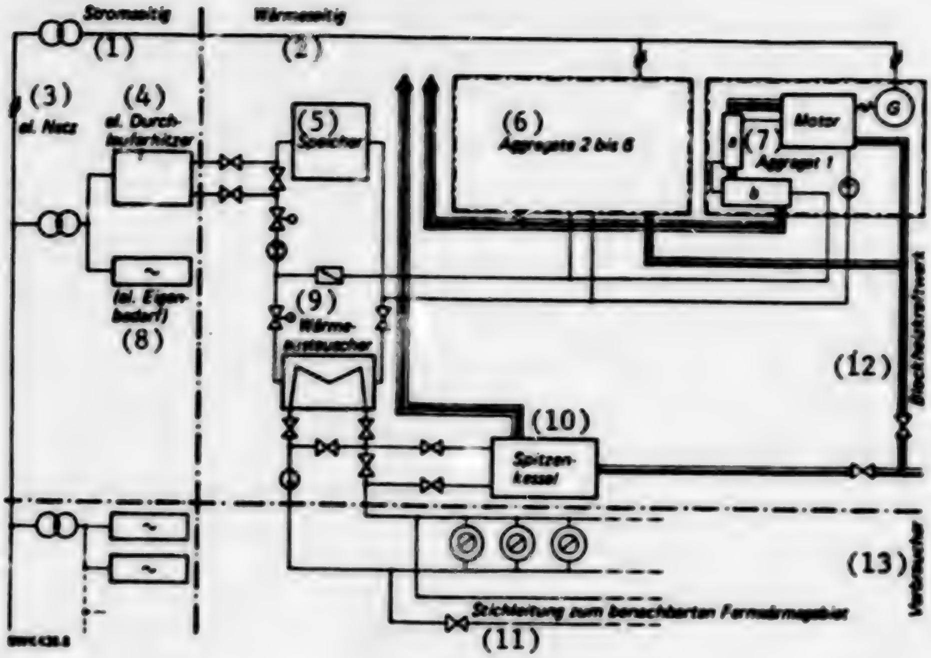

Figure 8. Circuit diagram of BHKW multi-motor plant in Heidenheim.

Key: a--Cooled waste gas collecting pipe; b--Waste gas heat exchanger; G--Asynchronous generator; 1--Current-side; 2--Heat-side; 3--Electric power grid; 4--Electric continuous-flow heater; 5--Storage tank; 6--Subsystems 2-6; 7--Subsystem 1; 8--In-house electric power requirements; 9--Heat exchanger; 10--Peak-load boiler; 11--Tapline leading to neighboring long-distance heat region; 12--Block thermal power plant; 13--Consumer.

Because the supply region remained the same, there was a unique opportunity to compare two very different types of BHKW plants in supplying the same consumer facility in energy and operations-management terms. The following important findings can be obtained in this fashion as far as BHKW technology is concerned:

Comparison of single-motor plants with multi-motor plants in terms of reliable supply and operation, consumption and cost figures, utilization intensities as a function of daily and seasonal conditions;

Comparison of two central units which vary greatly in terms of output (single-motor plant: 694 kw; multi-motor plant: 6 subsystems at 90 kw [each]);

Comparison especially regarding the control and regulating expenditure as well as blank current requirements in case of utilization of synchronous or asynchronous generators in block thermal power plants;

Comparison of theoretical findings with practical measurement results.

Answers to these questions should be worked out within the context of a comprehensive measurement program which is being carried out by the Energy Industry Research Agency with the support of the BMFT.

Summary

Block thermal power plants as a variant in the spectrum of power-heat coupling, because of their high overall utilization intensity of about 80%, contribute to efficient energy utilization. But, with a few exceptions, only the fossil energy sources represented by natural gas and fuel oil EL, which are available only to a limited degree, are being used at this time; this must be taken into consideration in any national economy studies for the purpose of reducing energy import dependence. In this connection one cannot at this time answer the question as to the extent to which the utilization of liquid or gaseous products of coal refinement as well as hydrogen would offer solutions that would be meaningful in terms of plant operation or the national economy as a whole.

The lessons learned as to the Heidenheim prototype plant as well as other BHKW plants which have gone into operation in the meantime show that, above all in terms of plant engineering and operations management, multi-motor plants reveal advantages over single-motor technology. Additional research and development work will be necessary in order to optimize this technology with regard to their possibilities. It is furthermore important to show where, through design measures, and how, through practical selection of system components and their dimensioning, the area of technically and economically meaningful utilization of block thermal power plants can be further expanded.

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5058
CSO:3102

BIOMEDICAL RESEARCHERS PROTEST GOVERNMENT R&D POLICIES

Paris L'HUMANITE in French 6 Nov 79 pp 1, 3

[Text] More than 2,000 scientists of the biomedical sector have just sent an "open letter" to the prime minister. They denounce the "reorientation" of the national research effort, which this summer has led, among other things, to a series of reforms of the major public agencies for scientific research.

The scientists stress that "these measures would result in scuttling French basic research and in subjecting existing potential to short-term financial interests." That is why they have made a formal appeal "to protect high-quality medical research."

The entire scientific community of medical research therefore condemns the government measures "which call into question the very existence of high-quality research," as emphasized in the text accompanying the petition.

With regard to biomedical research, implementation of the "Massenet plan" would oblige scientists to work on main areas of research defined as "priority" by a handful of industrial giants and a few "commissions" devoid of any elected representation of scientists. The latter are also "requested" --this "request" is accompanied by a threat to careers--to exhibit systematic "mobility" both thematically as well as geographically.

Finally, there are also the nonstatutory changes concerning the age limit for recruitment, arbitrarily set at 30 years for doctors and 27 years for other disciplines.

"These measures," the signers point out, "tend to destroy the research potential patiently established over the years." "From all evidence," they state, "they would result in scuttling French basic research and subjecting existing potential to short-term financial interests."

In their letter to the prime minister, they note that: "The establishment by the government of a research policy is a necessity; however, it must not sacrifice basic research and must leave ample room for the personal initiative of the scientific researcher to avoid the risk of stifling creativity. A priori determination of areas in which research will be fruitful would result in neglecting all areas in which scientific progress has been notable in recent years. A number of currently distinguished applications of research, from the 'scanner' to 'genetic engineering,' among many other examples, are derived from basic research whose economic and social effects could not be predicted by anyone. Sacrificing such research would lead to the stagnation or even reversal of the fight for good health."

That is why the members of the scientific and medical community make "a formal appeal that the measures imposed on INSERM [National Institute for Health and Medical Research] will be lifted."

To reinforce this appeal, professional research organizations will hold a rally in front of INSERM's headquarters at 101 Rue de Tolbiac, Paris, this afternoon, Tuesday, 6 November, at 5 pm.

Persons wishing to join this appeal may send their signatures to Dr Axel Kahn, Cochin CHU [University Hospital Center], 75674 Paris Cedex 14 or to Dr Gisele Guilbaud, 2 Rue d'Alesia, 75014 Paris.

11915
CSO: 3102

FRANCE

REVAMPING OF NATIONAL DATA PROCESSING SUPPORT PROGRAM

Details of Reorganization

Paris AFP SCIENCES in French 3 Jan 80 pp 17-18

[Text] Paris. Two New Government Data Processing Institutions. On 27 December 1979, two new public institutions, the INRIA [National Data Processing and Automation Research Institute] and the Data Processing Agency replaced the IRIA [Data Processing and Automation Research Institute], which was abolished by an executive decision published in the JOURNAL OFFICIEL on 27 September.

The INRIA, established on 27 December by a decision published in the JOURNAL OFFICIEL, will be directly responsible for research in data processing. The Data Processing Agency, whose establishment takes effect on 1 January, has the status of a public facility with an industrial and commercial nature, and will be responsible for the promotion of data processing activities in business.

Formerly the two activities, research and promotion, were included within the IRIA.

The heads of the INRIA and of the Data Processing Agency are, respectively, Mr J. L. Lions, former director of IRIA's LABORIA [Research Laboratory], and Mr Bernard Lorimy, a former official of the private data processing firm, FRANLAB.

The vice president of INRIA will be Mr Jean-Francois Denisse, who heads the research mission in the ministry for the universities. This ministry will play a significant role in the data processing reorganization since, along with the ministry of industry, which oversees the two new organizations, it will nominate the president of the INRIA.

The Data Processing Agency will implement the plan for the use of data processing in business, outside of the agencies concerned, the DIELI [Office of Electronic and Data Processing Industries] and the Data Processing Mission, which handles industrial policy for this sector.

Then, according to the ministry of industry, the personnel of the former IRIA will be spread between the two new organizations (approximately 350 people will go to the INRIA and about 40 to the Agency) and they will be hired with a contract similar to their former contract, without layoffs.

The separate location of the two organizations has not yet been determined, stated the ministry of industry.

The INRIA is governed by a board of directors, and includes a scientific council which, among other functions, is to advise the board of directors on research programs.

The board of directors includes:

a. The president of the institute, appointed for 3 years by an executive decision made at the proposal of the ministries of industry and the universities.

b. A representative of the ministry of the universities (vice president).

c. The director general of the CNRS [National Scientific Research Center] and the head of the Data Processing Agency (ex oficio members).

Furthermore, the decision transferred to the Data Processing Agency that part of the SESORI [Data Processing Research Synthesis and Orientation Service] which handles the direction of research and scientific followup of contracts.

The decision transferred to the INRIA the LABORIA [Data Processing and Automation Research Laboratory], the computer center, the data processing training service, the international scientific relations service, and the industrial research service.

Criticism From Left

Paris L'HUMANITE in French 9 Jan 80 p 8

[Article by Martine Bulard]

[Text] In order to try to overcome the opposiion on the part of the scientists, the government is justifying its "dirty tricks" by talking of an improved liaison between research and industry. This is so untrue that it has decided to dismantle the IRIA, which had specialized in applied research. This is just one example among many.

Remaining on the payroll of an organization that no longer exists is the fate of the workers of the IRIA, which is under the ministry of industry. Yesterday and Monday all the employees struck to "protest against this situation."

Established in 1967, the IRIA, which specialized in research on data processing and applied mathematics, was purely and simply abolished, effective 1 January of this year, by an executive decision. Its structure was split in two, with part of its activities to be transferred to the ADI [Data Processing Agency], which was created on the first of this year. The rest was to be included within the INRIA, which was created for this purpose.

The idea advanced by Giscard's staff is to dissociate the financing of research (which would now be up to the ADI) and the work itself (which will be concentrated within the INRIA). A complicated formula designed to mask the government's true objectives.

This objective is in fact to multiply contractual financing of research through external organizations, thus permitting greater "mobility"--in the Giscardian meaning of the term--for the studies done; this would make them fluctuate more than they could do with a more general financing system.

Research is thus being channeled, so it will evolve more as a function of the immediate needs of those in charge: in the name, of course, of better research-industry liaison.

But all the activities of the former IRIA were done in relation with industry. The research program was based on contracts with national enterprises such as EDF [French Electric Power Company], and Elf-Aquitaine, but also with private industry.

One of the major sections of the Institute, for example, was the conducting of pilot projects, in which groups of scientists and industrialists, people of varied backgrounds and expertise, worked closely together. This activity has now been endangered by the new governmental arrangements.

In fact, among the top people whom it has been decided to transfer to the Data Processing Agency are the 12 directors of these pilot projects, but the other scientists working on these projects will go to the INRIA. So on one side there will be the directors without projects, and on the other there will be the projects with no directors.

In other words, the reason of better relations between industry and research alleged by the government is a false pretext. Its intention is not to link them--that was the purpose of the IRIA, founded in the busy days of the Computer Plan, designed to seek greater independence. Its intention is actually to subordinate research to industry. And that is something quite different, which may endanger both our nation and the competitive nature of our industry.

We can understand that with such designs in mind, the government has left aside the employees concerned. A week after the elimination of the IRIA, the employees still don't know where and how they are going to work. A list of persons that it was decided "have an inclination to work in the Agency" has been drawn up, quite arbitrarily. And what does this new expression, "an inclination," really mean? What if they refuse? Not a word has been said about their new status.

As for the others, their place of work, their research: nothing has been divulged.

Since December 1978, the date of the first decisions to split the IRIA, the communist scientists, along with the personnel, have demanded that these measures be worked out democratically with those affected. Yesterday they again supported the struggle of the employees to hold on to their jobs, and for the future of applied research.

7679
CSO: 3102

ADVANCED ELECTRICAL RESEARCH DESCRIBED

Linear Engines

Paris L'USINE NOUVELLE in French 3 Jan 80 p 25

[Article by Olivier Fleurot]

> [Text] This year the firm Celduc is to develop an industrial prototype based on patents purchased from Anvar, The stake? Motorization of magnetically-borne, high-speed (300-400 km/hr) vehicles.

The firm Celduc (Electric Manufactures of the Center) has recently bought from the National Agency for the Application of Research the patents and the licence for the manufacture of the electromagnetic motor developed by an independent inventor, Jean Guimbal. This firm soon should be granted financial assistance to produce an industrial prototype if the file submitted by it to the Ministry of Industry is accepted.

Why revert to this technique, whose history is marked by more failures than successes? The stake is large. In the United States, as well as in Germany and Japan, designs for magnetically-borne, high-speed vehicles are under very serious study. For example, Japan Air Lines has been granted in March 1979 a $3 million subsidy from the Japanese Government to construct a prototype vehicle transporting 80 persons, the HSST-03. In Germany, similarly, a 1 km experimental line has been tested in Hamburg in 1979, and a 30 km line will be constructed this year. Several prototypes are under study in the United States. But no technically and economically reliable on-board linear electric motor exists anywhere.

In France the linear motor was considered to drive the Bertin ground-effect train. It appeared to have been more or less buried together with the ground-effect train. This did not take into consideration the perseverence of a few. First, that of Jean Guimbal who developed his own technology against wind and tide. While all over the world--including France with Merlin-Gerlin--research was conducted on motors comprising a single or double inductor whose winding moved along a flat rail, Jean Guimbal conceived a motor whose winding circulates inside a U-shaped rail. The result is that the overall efficiency of his motor is 0.5-0.6, while that of the others is closer to 0.2. This point is critical since a low overall efficiency requires the use of a very heavy and very powerful electronic control system, which is not economically feasible in the case of a motor carried by a half-train, half-airplane vehicle operating at 300 or 400 km/hr.

Another resolute agency is the Institut de recherche des transports (IRT = Transportation Research Institute) which, after discovering how to transpose to scale 1 the results obtained from small-scale models, conducted comparative tests to confirm the superiority of the U-shaped motor. IRT works also toward the preservation of the only test bench in the world designed for a normal-size prototype, the "big wheel" of Grenoble, whose repurchase is being negotiated.

Continuation of Industrial Development and Finding of a Partner

Specifically because of the results obtained last September in Grenoble with a prototype constructed at Celduc some German industrialists retrieved from their boxes projects of on-board drive, magnetically-borne vehicles. At this time they rely on the French to develop a motor and an electronic control system capable of being installed on their vehicles. Therefore, large German electrical firms, AEG in particular, are returning to the task.

The year 1980 will be decisive. What can the firm Celduc do? Marcel Guichard, its general manager, explains: "If the requested financial assistance is granted we shall continue the industrial development of the motor." Then an industrial partner capable of supplying the electronic control unit must be found. Who knows? A linear motor which, instead of being mounted on French vehicles, will be installed on Japanese, German, or American transport systems.

Organic Superconductors

Paris LE MONDE in French 13-14 Jan 80 p 25

[Article by Xavier Weeger]

> [Text] Will copper or aluminum be superseded some day by less costly organic compounds as electric-current conductors? Organic conductors resembling metals in many respects have been known for a few years. But a new step forward has just been made by French researchers from the observation of superconductivity effects in an organic compound.

Superconductivity--the property of some materials of presenting zero conductivity at very low temperatures--was observed for the first time in the world in an organic material. At the beginning of December 1979 researchers of Paris-Sud University, Solid-State Physics Laboratory (a laboratory associated with the National Center for Scientific Research), Denis Jerome and Michel Ribault, in collaboration with a Danish chemist, Mr Klaus Bechgaard of the Oersted Institute in Copenhagen, and with a third-year student, Mr Alain Mazaud, observed superconductivity in a carbon-, hydrogen-, selenium-, phosphorous-, and fluorine-base compound.

This observation, whose theoretical and applied consequences should be significant, is to be presented to the Academy of Sciences on Monday, 4 January, by Mr Jacques Friedel, and is the subject of an article which will be published soon in a scientific magazine, LE JOURNAL DE PHYSIQUE-LETTRES.

The superconductivity effect has been known for a very long time in the case of some metals: when a metal is cooled to a very low temperature near absolute zero (0°K, about -273°C) its resistivity characterizing the electrical resistance, tends to decrease. In the case of many metals, such as copper, the resistivity tends to a value different from zero. But in the case of other metals, such as lead, indium, and tin, the resistivity drops suddenly to zero when the temperature reaches a point lower than a given value called critical temperature.

This effect, which is observed not only in pure elements, but also in metallic compounds, for example vanadium-, gallium-, niobium- and aluminum-base compounds, is already being applied in practice, for example, in the manufacture of large superconductor magnets used in particle accelerators. Since the resistance is zero no heat develops on passage of an electric current (no Joule effect), and therefore very strong magnetic fields can be obtained.

Researchers in the entire world have attempted for a long time to obtain nonmetallic compounds presenting the same properties. Polymers behaving similarly in many respects to metals have been known for several years.* Superconductivity was observed in 1975 in a nonmetallic polymer composed of sulfur and nitrogen. But this polymer entails the major disadvantage of a very low critical temperature (0.3°K) which is therefore very difficult to obtain, while all the efforts of the researchers are directed toward obtaining materials of the highest possible critical temperature, even approaching room temperature (300°K) in the very remote future.

Strong Enthusiasm

In the middle seventies organic compounds aroused many hopes. In particular, highly interesting properties observed by American and French researchers at the same laboratory of the Orsay University in a compound named TTF-TCNQ, generated in the international scientific community a strong enthusiasm for this search for organic superconductive compounds. After many failures this enthusiasm became unfashionable until this time, and many teams abandoned the subject since 1978.

This was not the case of the Orsay team. It continued its work for about 6 years, especially by testing new compounds developed in collaboration with Mr Bechgaard of Copenhagen, in special conditions, particularly under high pressure.

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* See in particular "Des polymeres qui conduisent l'electricite" (Electrically-Conductive Polymers), by Jacques Livage, in LE MONDE, 22 September 1976.

Thus, at the beginning of December, a compound sinally produced after many so-to-say hit-and-miss experiments, finally provided the desired result, and at 0.9°K, under a pressure of 12 kilobars (12,000 atmospheres), superconductivity was observed in two specimens of $(TMTSF)_2PF_6$ [di (tetramethyltetraselenafulvalene)-hexafluorophosphate] which is a quasi-unidimensional conductor, i.e., in which electric current flows in a priviliged direction.

Some 200 organic conductors of the same type as tested before became insulators at very low temperatures. Instead of continuing downward their resistivity increased very suddenly. This is called the Peieris transition by the researchers. This time the Orsay researchers observed the reverse effect. Their compound has another property characteristic of superconductivity: the total disappearance of superconductivity on application of a magnetic field stronger than a determined value.

First of all, this result has theoretical consequences. It confirms the predictions of theoretical physicists working in France along with Professor Jacques Friedel, and by Soviet teams. In contrast to known organic conductors, which lose the properties related to those of the metals contained in them, compounds which retain this similarity to metals even near absolute zero can be obtained.

The Long-Term Work

The long-term work of the Orsay team should produce other consequences. In particular, a resumption of world research in this field may be expected since it has now been proved that the desired result--superconductivity in organic compounds--is achievable.

Naturally, much work remains to be done, and a temperature of 0.9°K is still not easily obtained. But the Orsay researchers maintain that preliminary signs of superconductivity appear from 77°K, i.e., at the boiling point of liquid nitrogen. By continuing their work with chemists they think that they can reasonably obtain organic compounds of critical temperature of about 20°K (liquefaction temperature of hydrogen), which would eliminate the use of the difficult and costly technology of liquid helium.

At a later time, much more extensive industrial fall out can be anticipated in the above-cited field of application of conductivity (large magnets). Electric technology industrialists work world wide on electric machines (e.g. alternators) using superconductivity. In the remote future they may use organic compounds instead of metals for this purpose.

At any rate much research is still necessary--Basic research since the theory of the observed effect is still not quite thoroughly understood; applied research to develop more manageable and more useful compounds, especially in respect to the necessary temperatures (remember for example that, in contrast to helium, liquid nitrogen is easily kept in Dewar-type vessels (thermos bottles)); and finally development, especially in chemical engineering, to be able to manufacture these compounds on the industrial scale.

It is still not possible at this time to predict whether one day organic compounds will replace metals in the everyday uses of electricity (for example, elimination of copper and aluminum in motors and electric wiring). However, the work of the Orsay researchers certainly demonstrates that organic conductors--also presenting other useful properties such as photoelectric effect in infrared radiation--have a bright future ahead of them.

9456
CSO: 3102

PROSPECTS FOR SPACE PROGRAM, RELATED INDUSTRIES

Rome AVIAZIONE in Italian Dec 79/Jan 80 pp 686-689

[Article by Antonio Teofilatto, general manager of the National Aerospace Company: "How Not To Stay Out of a Rich Market"]

> [Text] Approval of the national space plan, long delayed and often opposed in various political and industrial circles, might open up to Italy valuable prospects of "capturing" a slice of the market potential of space telecommunications. This periodical has requested the opinion on the importance of the plan to Italian industry of one of our country's best known space experts, Dr Teofilatto, general manager of the National Aerospace Company, one of the "fathers" of the Sirio satellite, who replies with this article.

It should be pointed out that Italy's participation in international and European space programs requires an industrial structure constantly better fitted for meeting competition by other countries. A good position can be obtained and maintained by means of an effort of systematistic and technological qualification achievable only in the national sphere, which, since its start with the Sirio project, will have continuity owing to the 1979-1983 Italian space plan. The new plan is oriented toward completed objectives. That stems from an examination of mature technical experience and, by coordinating the important potentialities of the nation's space sector, it is the essential instrument for guaranteeing to Italy's industry technological and systematistic capability suitable for coping with the country's future domestic requirements and the increasing international demand for space products. The plan approved recently by CIPE [Interministerial Committee for Economic Planning] assigns 200 billion lire (98 by 31 December 1981 and 102 for 1982 and 1983) to space activity, specifying several lines of development like telecommunications, space propulsion systems, experiments of the ESA [European Space Agency] Spacelab, telesurveying, basic research and space technologies extended to future peaceful utilization of space.

Of the 98 billion for the 1979-1981 period, 52 are for telecommunications activities, for the project of a ground-space system operating high-capacity 20 to 30 gigahertz point-to-point links. The satellite that will serve this system with preoperational characteristics during the 1980's will be able to make multiband links and will have innovative features suitable for making possible a degree of technology fitted for the international growth trends. In this way, the systematistic capabilities acquired with the Sirio-1 project are consolidated and are revived with experimentation on telecommunications technologies to be introduced in Italy in the 1990's (or perhaps sooner). In short, the plan is meant to be an instrument for activating progress in the field of space activities. It appears to be an excellent solution to utilization of the resources available in the sector. It tends to develop autonomous capabilities and products (components, subsystems and systems) to cope hopefully with the country's future requirements; to a policy of promoting and expanding structures able to acquire international orders, for a contribution to qualifying exports with a high degree of technology; to development of specialized labor forces (instruction, training and job qualification) in sectors that make possible a technological fallout toward other industrial activities to the benefit of the national community; to qualify Italy's presence in ESA better in systematistic terms by assuming that trailing function that makes it possible to put returns back in balance. Establishment and approval of the space plan were possible only because the Sirio satellite was truly successful: 2 years of life in orbit -- as had been planned -- with constant, completely satisfactory operation (one single breakdown minor in nature, therefore much below statistical indications, and with no effect on the experimental service); possibility of extending its operational life an additional 80 percent; utilization by American experimenters, because of some of the special features of the project, for unscheduled purposes (NASA-JPL, NASA-Boston University). Therefore, Sirio is the basis for the new programs and the occasion for the political authority to take over on its own account the planning of future space activities Italian in scope as well as within the scope of the European Space Agency (ESA) whose programs are financed by Italy with around 50 billion a year. Space is opening up new possibilities in the sector of telecommunications, which is evolving from the research phase toward constantly greater technological content. Constant competition is in progress in the international field. The drastic reduction in launching costs obtainable in the 1980's by using the NASA space shuttle will make satellite TLC systems still more competitive. The present cost of a launch amounts to about twice the cost of the satellite. By using the space shuttle, the launching cost in the near future may be about half the cost of the satellite, because the launcher is reusable and suitable for multiple launchings. With implementation of the national plan, Italy will be able to be in a good position for acquiring no small slice of the international market potential for telecommunications systems at the "national domestic" and "regional" level. It is necessary, therefore, to take advantage of the opportunity offered by turning systematization and planning activities toward criteria of "expenditure effectiveness." Only in that way shall we be able not only to become independent of foreign nations in this sector, but also active with exports with a high degree of technology. It should be stressed that past experience forbids us from losing time. With approval of the plan and with an industrial structure already prepared, we must start the achievement phase, that is to say that we must establish the agency that will administer the funds of the plan and that will make decisions making work of research, planning and development possible.

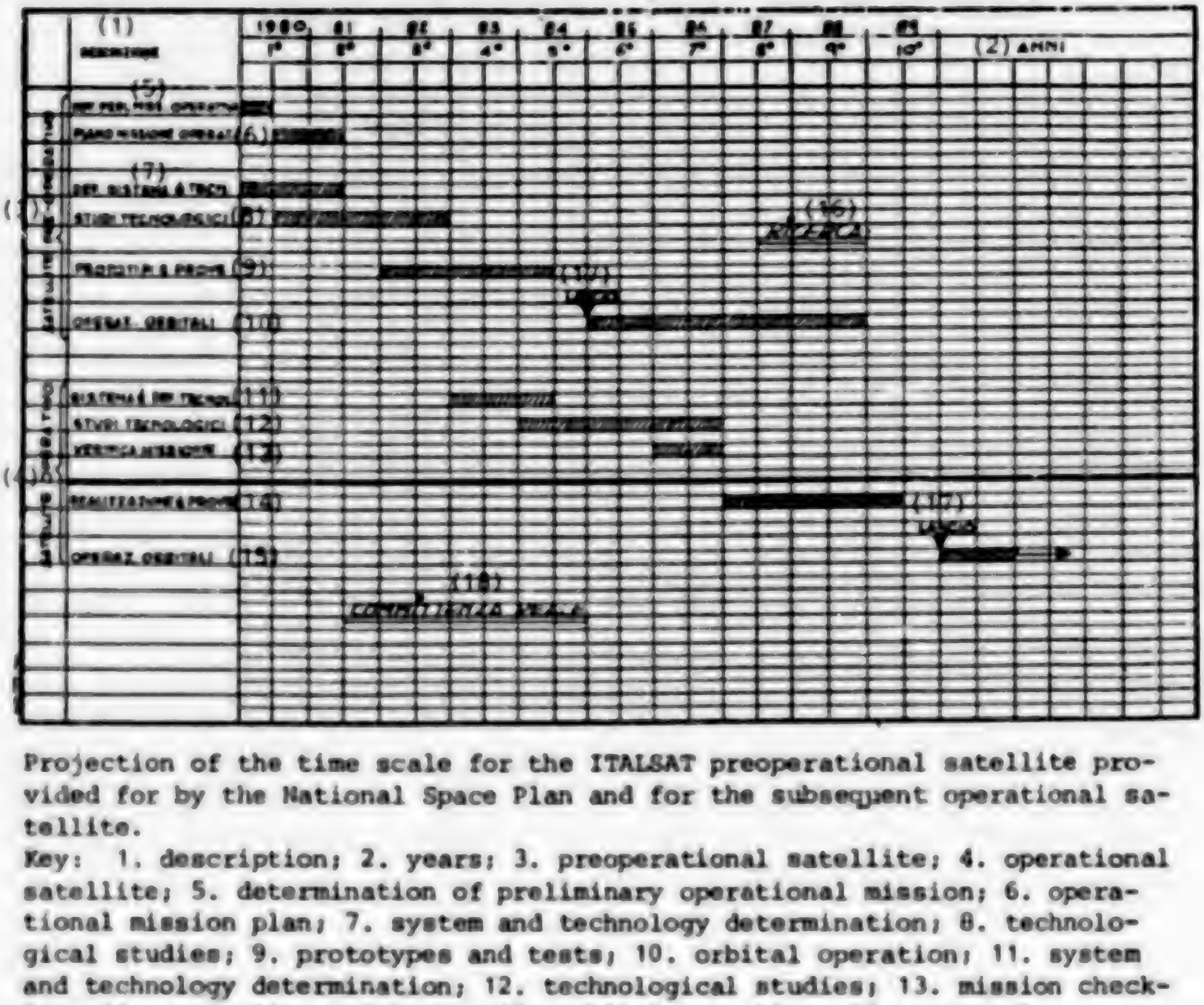
The market that we can hold in sight can be acquired both by furnishing entire systems and by means of participation with highly specialized subsystems. Participation with subsystems implies activity in systems designed by others (prime ordering activity American or European). In practice, however, a limitation is placed on the acquirable market and a sizable industrial "product" is not achieved. This kind of participation entails a constant demonstration of credibility difficult to achieve except by means of systematistic qualification. Therefore, presence in the systematistic role is an essential requirement not only for having proprietary rights to the product to support independent commercial initiatives, but also for participating in programs of international collaboration. The role of a systematist entails guidelines and independent choices on projects and it makes possible -- with investments in funds and equipment -- a selective preparation and pertinent updating in the more advanced technological sectors. If that role is missing, there are no opportunies and capabilites for bringing the choices to maturity, advanced technologies have no continuity of motivation, resulting in a loss of keeping abreast of the market. In this connection, account should be taken of the example of ESA and comparison should be made with Sirio. In the past, by participating in ESA programs with a share ranging between 14 and 18 percent, Italy did not have an opportunity to fix itself internationally in a systematistic role. It was unable to come up with products widely important enough to offer on the market. With the Sirio program Italy (industries and government-managed agencies) was faced with an overall system project. Its industry developed systematistic functions by making cost-efficiency choices, by channeling investments and human resources toward the most appropriate sectors, by thus coming up with a qualified industrial product. At present, Italian industry is accepted by ESA as a prime contractor in charge of system for Sirio-2, but it is especially sought as a partner in the sector of advanced telecommunications in which Sirio has created the premises for qualification. These industrial initiatives can be maintained and potentiated -- in a definitely expanding market -- only if qualification and specialization are encouraged. Therefore, a second step is expedient in assumption of the systematistic role in the telecommunications sector with an experimental-preoperational project. Once the impossibility that this step will come about in the field of participation in ESA has been confirmed, owing to the position of strength acquired by the leading European partners, like France, Germany and Great Britain which intend to retain their priority role, it follows that a project of a systematistic nature oriented toward advanced technologies can be tackled at present only domestically. A principle of "autarky" is not affirmed with this. By participating in ESA, Italy benefits from the European technological context and contributes to some specialistic sectors, but it operates on choices made by others. That restricts its autonomy in view of its own future systems and limits the possibility of expanding its market. It should be pointed out as an example that the same technological program that Italy entrusted with ad hoc financing to ESA management might be left without a future, if the national program did not provide an incentive to their use. Therefore, penetration in the international market requires that subsequent systematistic experience possible with the national space plan.

What future role is conceivable for industry resulting from this plan? The market requires satellites especially for telecommunications applications. There are not very many industries all over the world that have produced satellite systems, although some have dozens of projects to their credit. With Sirio, Italy's industry has shown that it is capable of acting in a limited time (34 months from contract signing to launching) comparable to the time taken by the most advanced industries ("30-month" programs are typical of space industry in the United States). Thus, in Italy, there is a structure making it possible to tackle problems of the sector. It is, therefore, expedient for a "product" chosen in those sectors complemetary to the ones in which American industry and the strongest European firms have established themselves to be shaped up, with a view to a slice of the market as wide as possible. Therefore, that choice can be assumed for those products with a flexible design suitable both for the requirements of third world and Italian teledistribution and point-to-point telephone services. These are the sectors in which it is foreseeable, at present, that there will be most demand for satellites with a medium to large capacity, tailored to national dimensions. In this connection, account should also be taken of the fact that the domestic telephone services of developing countries, starting with utilization of the international INTELSAT system, will tend to pass into the sphere of individual countries as the service, in expanding, gradually takes on greater political complexity. It is also necessary to aim at a low-cost "satellite product" in orbit, that is to say a modular, expandable project best suited for the NASA space shuttle compatible with traditional launching facilities.

In addition, it is necessary to prepare the launch vehicle auxiliary to the NASA space shuttle, which -- incorporated with the satellite -- will make maximum overall economy possible. By meeting these requirements, Italian industry can ready itself for the role of European industrialist for the production of regional satellites and can have the requisite preparation and capability of furnishing the national telecommunications system. (The auxiliary launch vehicle will also be marketable as a separate subsystem, suitable for any launching of a certain kind both applicative and scientific). It is also necessary to be present in the sector of direct television distribution. The satellite's design should make it possible to perform missions in the country and to offer services to neighboring areas.

It is worth while to consolidate these remarks, which seem to make the possibility for active Italian presence in the space sector and in the ground sector of telecommunications contingent on public investments, with all that has taken place in the United States. As is known, NASA, the American Government space agency that had set in motion the technological and industrial scenario in the United States and outside, reduced considerably its volume of activity, after the Apollo manned-flight programs. In the "cut" operation, space telecommunications programs underwent a decrease in financing from $40-$60 million a year in the 1968-1973 period to less than $10 million a year from 1975 on. At present, American industry is complaining about not having been able to retain its unconditioned primacy in the sector. It offers as proof of this the fact that European industrial participation in the INTELSAT programs, which was less than 5 percent in INTELSAT IV (1969-1971) has reached about 30 percent in the INTELSAT V project. Because INTELSAT activities are handled in a highly competitive context, this means that with government research and development programs European industry has acquired competitiveness with regard to United States industry no longer fed by NASA research and development programs. NASA, which is revising its positions, is again investing in the space telecommunications sector, making provision for amounts on the order of $50 million a year in the 1980-1983 period.

Average annual expenditure for carrying out the Italian program will be around 40 billion [lire]. This figure does not entirely find expression in jobs for our industry, in view of the fact that some parts or services are bought abroad. Based on experience with Sirio, they should amount to around 6 percent, excluding the cost of launching. Therefore, it may be estimated that the program will generate, in Italy, an average annual volume of work amounting to around 38 billion. Added to this work is everything stemming from participation in the European Space Agency, which, with 50 billion lire a year, should generate around 40 billion in contracts for our industry (equal to 80 percent of the outlays). Altogether, our space industry should be able to count on an annual turnover of between 70 and 80 billion, including a direct involvement of around 1,500 specialized technicians who, added to the indirect manufacturing personnel and personnel employed on subcontracts, should mean employment for about 4,000-5,000 persons. According to estimates derived from an ANIE [National Association of Electrical and Electronic Industries] report, in 1975 our industry had human resources of over 1,300 specialized employees in the sector. Implementation of the program might result in an appreciable increase in employment in the space sector. New specialized forces will be required for this expansion. They can best be typified by taking the typical satellite product as an example. In the past, "scientists" were the ones who produced space objects. At present, satellite projects are developed by "engineers" with the assistance of technicians and skilled workmen. If we examine the makeup of a telecommunications satellite with the criterion of expenditure, we see that we have to spend the following: 20 percent for the system and management, 6 percent for the mechanical and thermal structure, 7 percent for auxiliary propulsion (apogee engine, small attitude control motors), 45 percent for electronics (packages for missions and onboard services), 12 percent for power supply, 5 percent for launching operations, 5 percent for testing and inspection equipment, in addition to launching into orbital control and operation. This distribution gives an idea of the specializations contained in the activity. By degree of specialization, it may be said that, of every 100 employees, 35 are engineers and graduates, 40 are technician-specialists, 5 are assigned to quality control, 15 are skilled workmen, 5 are workmen. Another 100 employees work alongside the above for support services with more general skills and for unskilled activities. At present, schools train engineers with aerospace specialty, more aeronautical than space. They do not train the other skilled categories at the required intermediate levels for industry. Industry provides for itself by taking charge of personnel training, by operating with labor forces drawn from other skilled sectors, primarily electronics, but expansion of the sector will really be possible, if the new labor forces introduced are suitably trained by means of an osmosis between school and industry. The expectations that the community and the industrial and labor world place in the nation's space sector in terms of skilled labor, acquirable market and prospects for development in a sector expanding so rapidly become clear from this survey that has been presented.



Projection of the time scale for the ITALSAT preoperational satellite provided for by the National Space Plan and for the subsequent operational satellite.

Key: 1. description; 2. years; 3. preoperational satellite; 4. operational satellite; 5. determination of preliminary operational mission; 6. operational mission plan; 7. system and technology determination; 8. technological studies; 9. prototypes and tests; 10. orbital operation; 11. system and technology determination; 12. technological studies; 13. mission checking; 14. production and tests; 15. orbital operation; 16. research; 17. launching; 18. actual commitment

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ITALY

EXPERIMENTAL GAS-OIL ENGINE TESTED

Rome FONTI DI ENERGIA ALTERNATIVE in Italian No 3, May/Jun 79 pp 43-52

[Article by Mauro Marchionni, Vincenzo Naso, Giorgio Paccani and Vincenzo Venditti: "Energy Diversification--Internal-Combustion Controlled-Ignition Reciprocating Engine Fueled by Gas-Oil"]

[Text] 1. Introduction

The problems of energy and pollution have particularly serious aspects in the field of transport [1, 2, 3]. Among the problems with the thermal engines used in this field, those of the controlled-ignition internal-combustion reciprocating engines therefore appear especially critical [4, 5].

In this regard, for a series of reasons that will be set out below, the idea was conceived of conducting a feasibility study on an unconventional type of fuel system for such engines. Specifically, the intention was to verify the possibility of fueling them with mixtures of low-octane hydrocarbons, with, obviously, satisfactory regularity of operation and with improvement, where possible, of the overall performance characteristics of the engine and of its pollution index.

The intention is to achieve the necessary modifications of the chemical structure of the preselected fuel by doing cracking by means of a thermal reactor installed on the vehicle and consisting of a heat exchanger which uses the exhaust gases of the engine itself as the heating fluid.

In this paper, after a brief review of the goals of the research, the test apparatus built is described, the first positive experimental results obtained are reported, and the research program by which it is intended to continue the investigation is outlined.

2. Goals of the Proposed Solution

Certain aspects of the idea of using gas-oil as a fuel for internal-combustion controlled-ignition reciprocating engines involve some unknowns and caused the present authors quite a few perplexities. This fact is due to two reasons that are, so to speak, inherent in the energy question:

(a) gas-oil is a fuel in great demand for a wide variety of uses; therefore, there is no immediate need for it to be found a place in the market for commercial use;

(b) the crude-oil refining system is naturally predisposed to production of a considerable proportion of gasolines, which it is therefore advisable to make use of.

Nevertheless, the following considerations encouraged the undertaking of the present study:

(a) it is a self-evident rule of energy strategy to increase the "polycombustibility" of thermal engines as much as possible.

This approach is of particular interest in the case of special and military uses, and also, more generally, because of the possibility which an engine thus offers of adapting more flexibly to local availability of energy supplies [1, 2, 5];

(b) generally speaking, even considering the need to learn more about the interrelated aspects of driving, energy considerations and pollution, the cost of the gas-oil to be used in the modified engine appears to be considerably lower than that of gasolines [3, 5];

(c) the use of fuel with fewer antiknock additives, or none at all--and therefore less polluting by this very fact--appears possible[1];

(d) in the proposed solution, the fraction of exhaust-gas sensible heat recovered is used partly for the cracking reaction and partly for preheating of the fuel to be burned, with obvious thermodynamic advantages in terms of heat recovery and thermal regeneration.[2]

3. Test Installation Built - Details of Operation

Since no information relating to previous research on the subject proved available in the technical literature, it was decided to subdivide the research into two phases. The first phase comprises the feasibility study, undertaken with strict criteria, but criteria of simplicity and economy also; it will be followed by a complete parametric analysis.

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[1] In the course of this paper it will also be stressed that improvements in the engine's performance characteristics from the point of view of pollution are expected for other reasons also.

[2] It should indeed be noted that along with this advantage there is the corresponding disadvantage of a reduction of the coefficient of filling, to a degree that is not easy to evaluate beforehand.

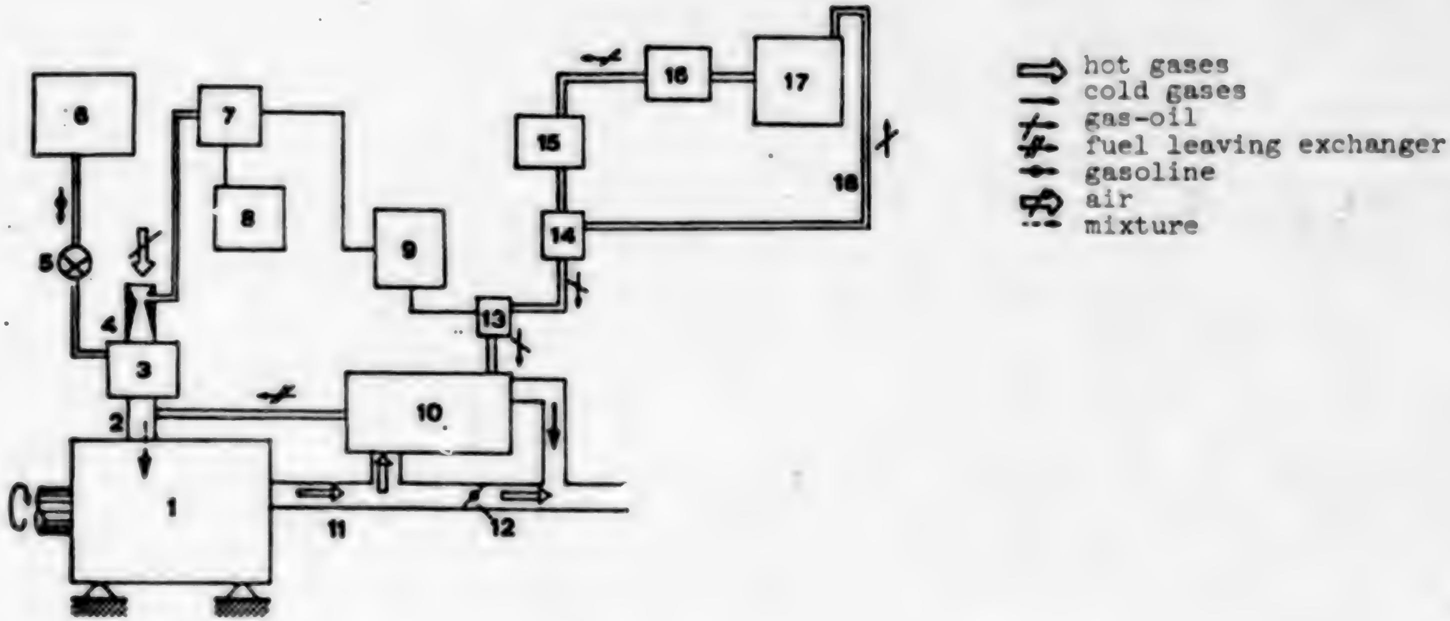


Figure 1. General diagram of the installation

The hot gases coming from the engine (1) are sent into the heat exchanger (10) through a system of collectors (11) that has a bypass and a switching valve (12). The gas-oil arrives at the exchanger from the electroinjector (13); it reaches this under pressure by means of the electropump (15) which draws through the filter (16) from the tank (17). The pressure in the gas-oil feeding circuit is kept constant by the pressure switch (14), which has a breather tube (18). The fuel coming from the exchanger is put into the air-intake tube at the junction (2) downstream from the carburetor (3). The system for regulating gas-oil feed to the exchanger acts by electrical impulses which command the opening of the electroinjector. These pulses come from the electronic power plant (9), which elaborates the pressure signal taken from the throat section of the venturi (4) at the intake upstream from the carburetor. The element that transduces the pressure measurement into the proper electrical signal to be sent to the power plant is the pressure sensor (7), powered by the wave generator (8). At startup, which is done conventionally, gasoline is drawn from the tank (6) and sent to the carburetor (3); in the tube is inserted an intercept valve (5) which interrupts the fuel flow when the switchover to gas-oil is done.

Our purpose here is to report on the first phase, the installation built to carry it out, and the indications resulting from it.

We shall now describe the functioning planned for the test apparatus, a block diagram of which is shown in Figure 1, with an overall photograph in Figure 2.

In the startup phase, the engine functions in the conventional ways (it could not do otherwise), with the sole variant consisting in the fact that the exhaust gases are conveyed into the exchanger so as to heat it.

Indeed, operation with gas-oil fueling is initiated only when the temperature in the exchanger's internal channels is high enough to permit production of the necessary cracking reactions in the gas-oil fuel.

When this occurs, the fueling "changeover" can be done. This operation consists of three phases:

--shutoff of the flow of gasoline to the carburetor;
--emptying of the carburetor float chamber;
--startup of the gas-oil fuel-supply system.

During nonconventional operation, any shutting-off of the engine does not imply that the very next startup will occur in the ways indicated above; in such case, with the engine well warmed up, it is in fact possible to start up directly with gas-oil.

The gas-oil, kept under pressure, is put into the exchanger by means of an electroinjector; from there, after the chemical-physical transformations if undergoes, it goes on to the intake ducts.

There is usually a different optimum quantity of gas-oil to be injected into the cylinders for each operating condition, and the dosage is done by a regulating system. This can be automatic or manual.

Finally, no changeover is necessary when the engine is shut off.

Table I. Summary of Characteristics of Engine Used

Type of engine:	FIAT 110D.000	Compression ratio:	7.1
Cycle and strokes	8 (4-stroke)	Maximum power (DIN):	13.2 kW
Number of cylinders:	2, vertical	Corresponding speed:	4,600 RPM
Cylinder diameter:	67.4 mm	Maximum torque (DIN):	30.4 N - m
Piston stroke:	70 mm	Corresponding speed:	3,000 RPM
Total displacement:	499.5 cm^3	Timing system:	overhead-valve type

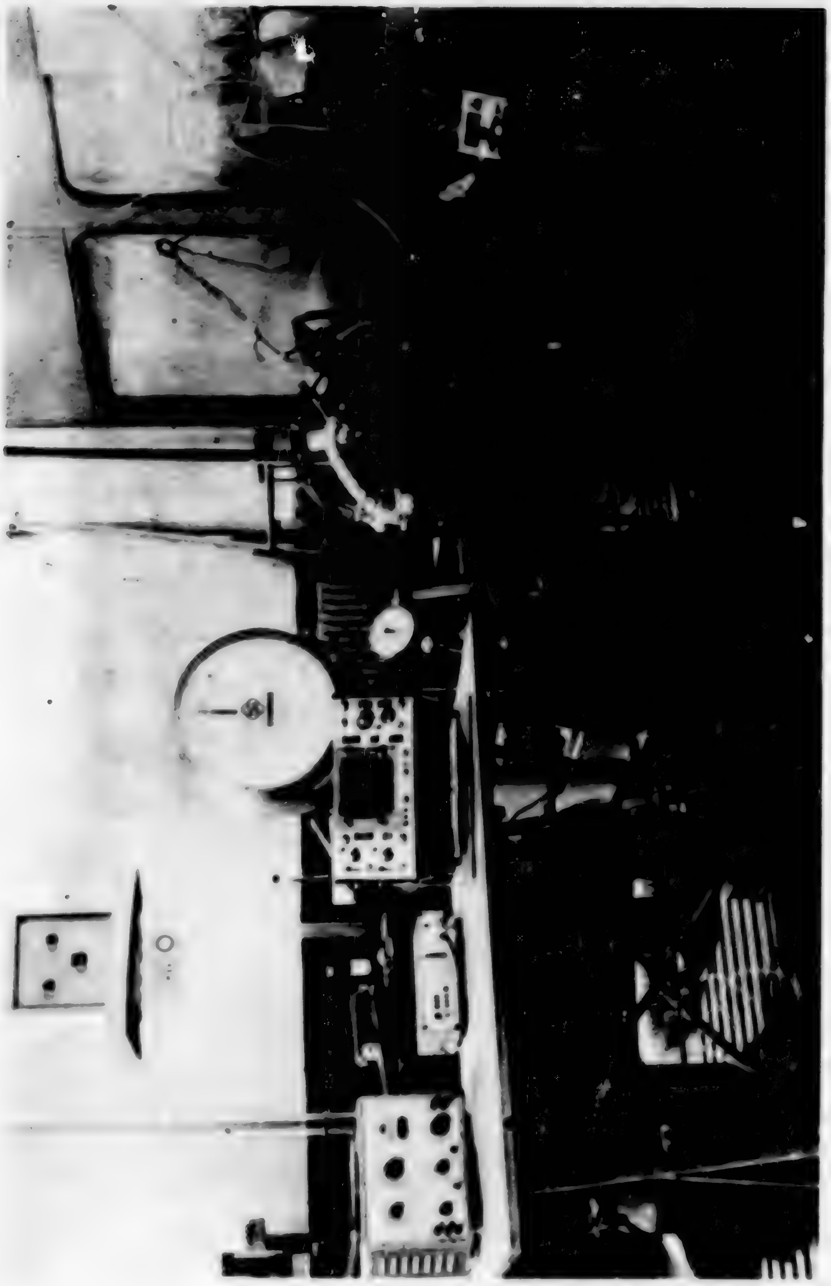


Figure 2. Test installation

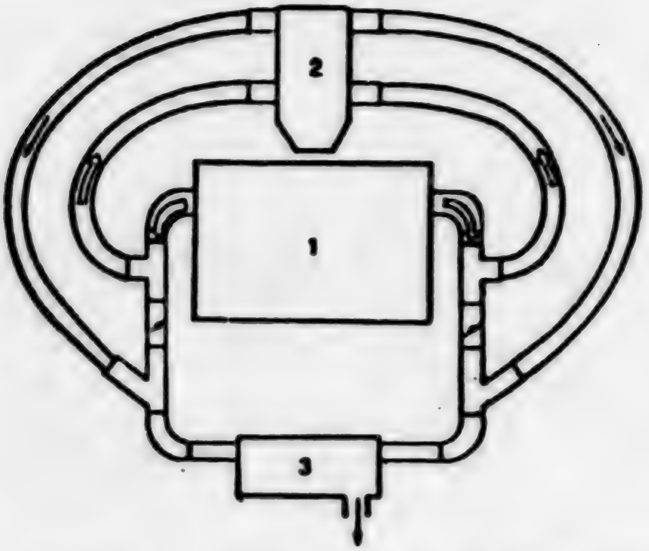


Figure 3. Course traveled by burned gases

1. Engine
2. Heat exchanger
3. Exhaust muffler

⇨ Hot exhaust gases

→ Cold exhaust gases

4. Characteristics of the Components of the Installation

As we have seen, the installation is composed of the following set of components: the engine, the exhaust manifolds, the heat exchanger, the gas-oil circuit, the gasoline circuit, the apparatus for regulation (automatic or manual) of fuel dosage, and the measurement apparatus.

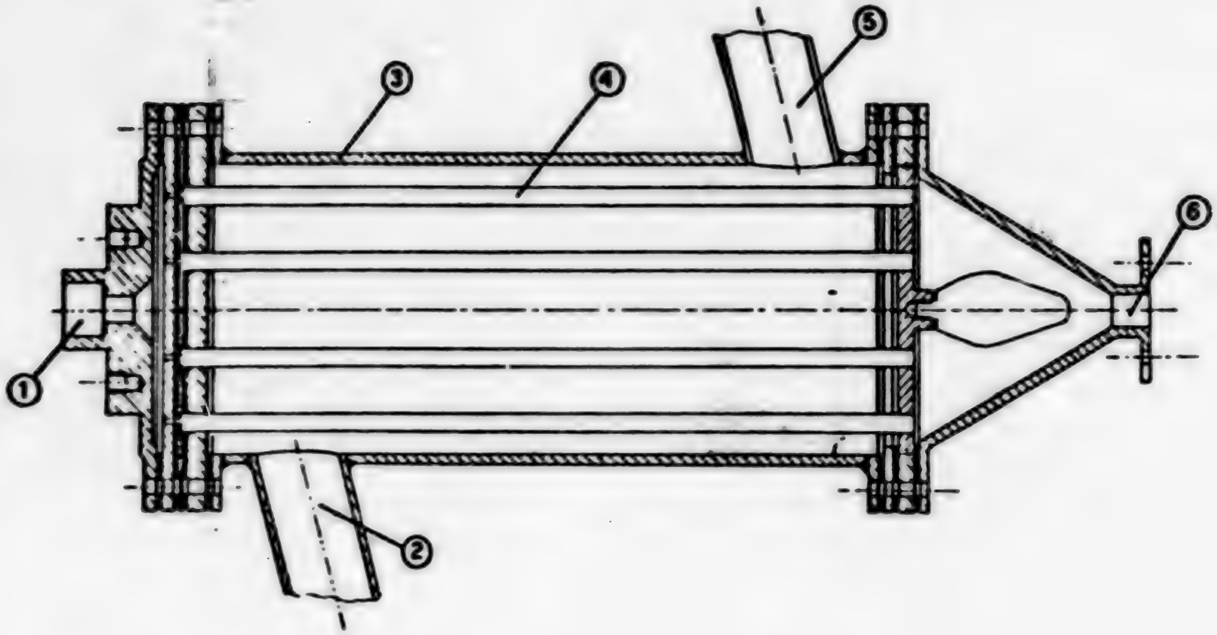
The last-named two apparatuses will be dealt with in later paragraphs; immediately below, the characteristics of each of the other components are examined.

4.1 Engine--The engine used for the first experimentation is a FIAT 110D000, the principal characteristics of which are given in Table I.

In the line of thinking referred to in section 3., the choice was based on the following considerations:

(a) simplicity and economy both of the engine and of the modifications required for preparation of the test installation relating to it;

(b) general characteristics suitable for the tests to be done--in particular, low compression ratio and consequent high knock threshold, certainly one of the most critical aspects of the investigation.



1. Electroinjector housing
2. Manifold for outgoing exhaust gases
3. External cylindrical shell
4. Element of tube set
5. Manifold for incoming exhaust gases
6. Fuel outlet

Figure 4. Sectional view of the heat exchanger

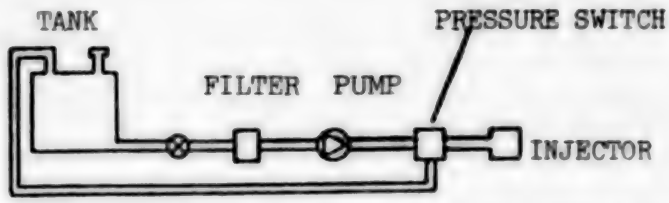


Figure 5. Diagram of gas-oil fuel-supply circuit

4.2 Exhaust Apparatus--It is designed in such a way as to offer the burned gases two alternative courses of travel: one goes to the muffler through the heat exchanger, while the other goes directly to the muffler. Adequate insulation has been provided for the muffler.

The percentage of the gases going through one circuit or the other is continuously regulable by means of two butterfly valves (Figure 3).

4.3 Heat Exchanger--It is of the countercurrent type and is composed of a cylindrical steel body through which the hot fumes run and contains a set of copper tubes flange-mounted to the ends, through which the gas-oil flows (Figure 4).

4.4 Gas-Oil Fuel-Supply Apparatus--Figure 5 gives a diagram of this apparatus. It is composed, in order, of the following components:

(a) a tank;
(b) a filter;
(c) an electric pump of volumetric type that functions on 12 V DC and furnishes a head of 0.2 MPa;
(d) a pressure switch, sensitive to pressure variations on the order of 50 Pa, with return shunting to the tank;
(e) a Bosch electroinjector of a type commonly used for indirect injection of gasoline and commanded by a series of square electrical impulses, of constant frequency and variable symmetry (Figure 6).

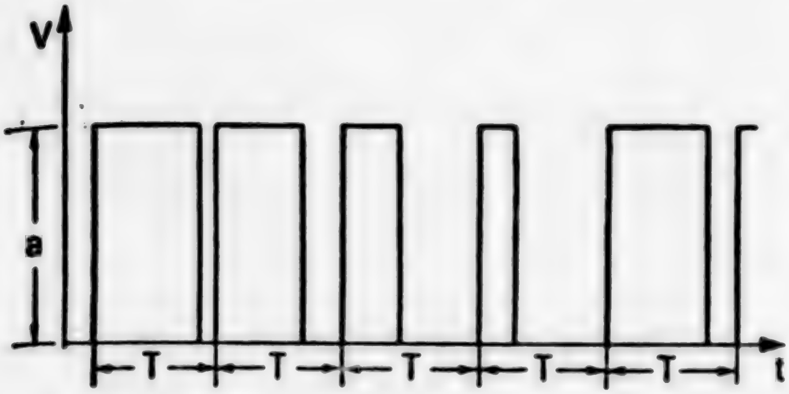


Figure 6. Electrical command impulses of the electroinjector

The fuel that leaves the heat exchanger is sent through two symmetrical ducts to a junction downstream from the carburetor and behind the air-intake manifold (Figure 7).

Figure 7. Carburetor junction

4.5 Gasoline Circuit--There are no modifications of the conventional circuit, with the exception of the insertion of an interception valve, necessary for interrupting the flow to the carburetor when operation on gas-oil is initiated.

5. Regulation Apparatuses

5.1 Automatic Regulation Apparatus--The total apparatus (Figure 8) comprises the following components:

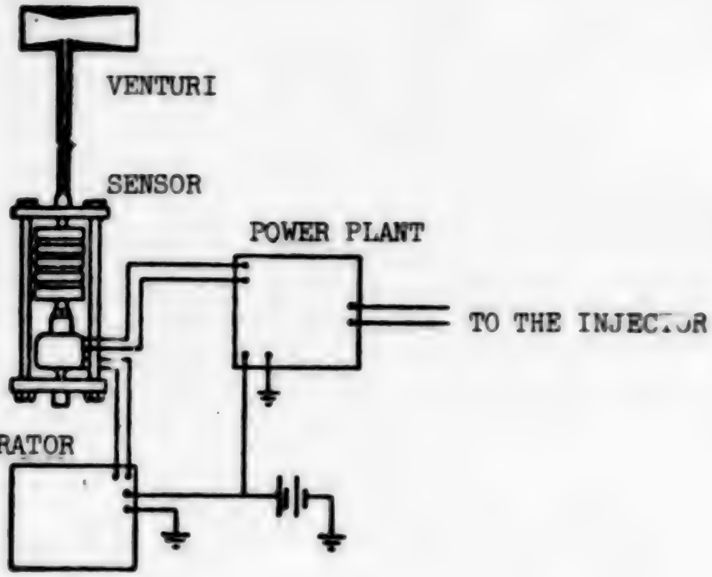


Figure 8. Automatic regulation apparatus

(a) a venturi (Figure 9) positioned upstream from the carburetor; the abovementioned static-pressure tube is located in its throat;

(b) a pressure sensor, consisting of a differential transformer, in which the movement of the plunger is caused by contraction of a diaphragm connected to the venturi intake. The outgoing signal from this instrument is sent to the electronic power plant;

(c) a sine-wave generator that powers the primary of the differential transformer of the preceding sensor; it permits powering at variable frequency and variable voltage;

(d) an electronic power plant for command of the electroinjector; it is composed of four sections (Figure 10):

  (i) circuit generating constant-frequency triangular signals;

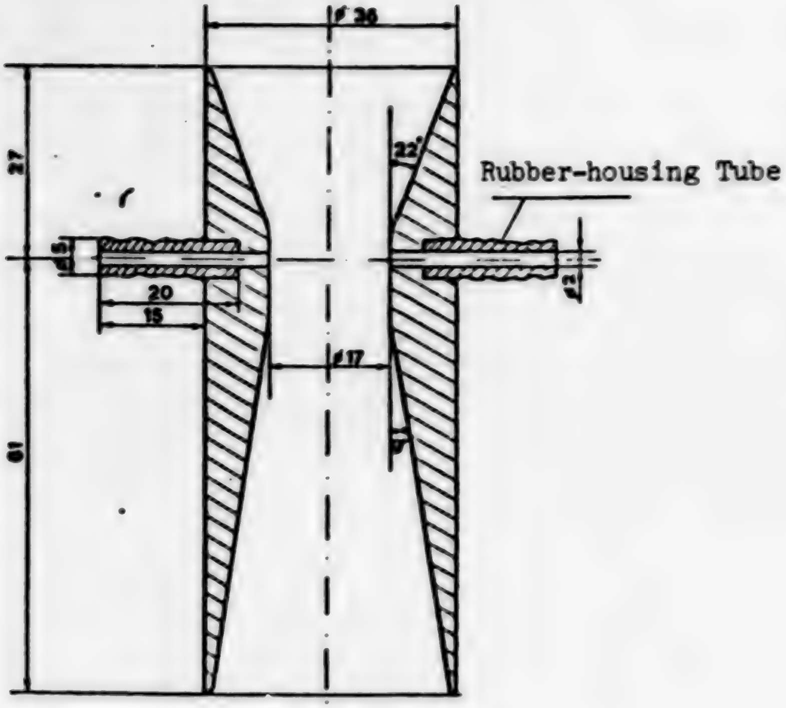


Figure 9. Venturi with static-pressure tube

(ii) circuit which, operating in parallel with the first one, elaborates the signal from the pressure sensor, making it continuous;

(iii) circuit which, operating in series in parallel with the first two, compares their signals, elaborating them so as to obtain one with rectangular wave, of constant frequency (equal to that of the triangular signal) and variable duration (symmetry);

(iv) power circuit;

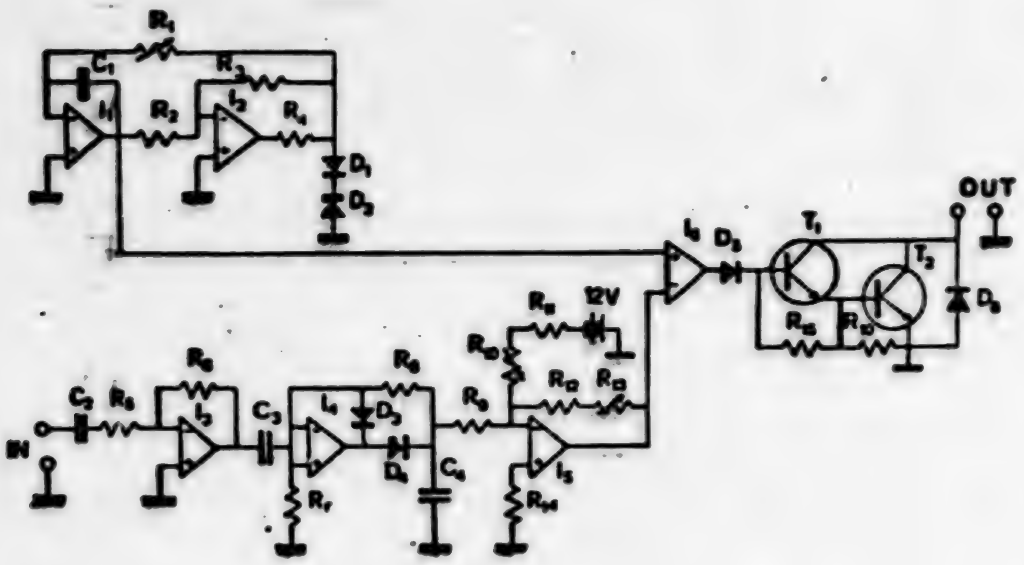
(e) electroinjector (already described.

5.2 Manual Regulation Apparatus--It consists of the following components:

(a) a rectangular-wave generator, with output modulable for frequency and symmetry;

(b) a power amplifier, for powering the electroinjector; it is composed of the last stage of the electronic power plant;

(c) an electroinjector (already described).



$R_1 = 100K\Omega$
$R_2 = 22K\Omega$
$R_3 = 22K\Omega$
$R_4 = 830K\Omega$
$R_5 = 10K\Omega$
$R_6 = 270K\Omega$
$R_7 = 100K\Omega$
$R_8 = 100K\Omega$
$R_9 = 100K\Omega$
$R_{10} = 100K\Omega$
$R_{11} = 150K\Omega$
$R_{12} = 100K\Omega$
$R_{13} = 0.47M\Omega$
$R_{14} = 82K\Omega$
$R_{15} = 15K\Omega$
$R_{16} = 1K\Omega$
$D_1 = D_2 = 6V8$
$D_3 = D_4 = OA202$
$D_5 = OA202$
$D_6 = ZENER 30V 1W$
$T_1 = BC266$
$T_2 = 2N3055$
$C_1 = 0{,}047\mu F$
$C_2 = 2\mu F$
$C_3 = 0{,}22\mu F$
$C_4 = 0{,}47\mu F$
$I_1 = I_2 = I_3 = I_4 = I_5 = I_6 = \mu A741$

Figure 10. Diagram of electronic control power plant

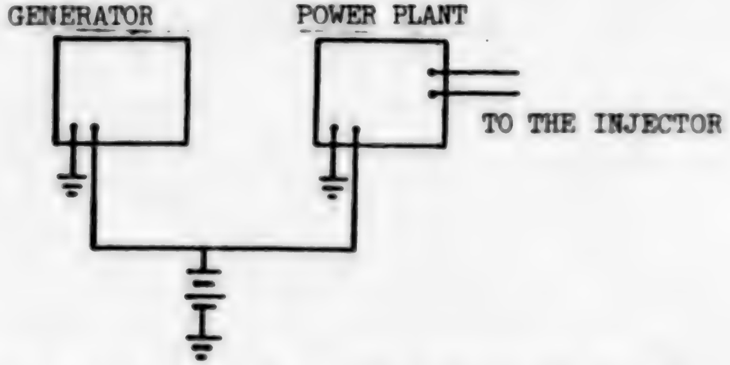


Figure 11. Diagram of manual regulation system

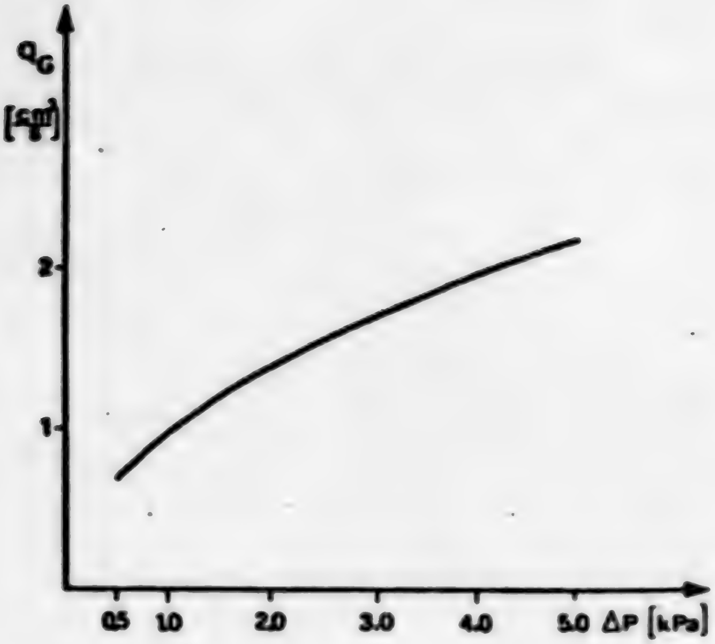


Figure 12. Curve of gas-oil flow with variation of Δp

Manual regulation is possible per the diagram in Figure 11; it makes it possible to work with variation of gas-oil flow independently of the particular engine speed.

This is useful mainly for the following reasons:

(a) it makes it possible to take account of the not-yet-defined modifications of chemical structure undergone by the fuel in the exchanger;

(b) it offers the possibility of working with different air-fuel ratios.

5.3 Setting--The test-bench experimentation conditions and the requirement to create an apparatus with characteristics of simplicity and reliability led to a method for automatic regulation in function of intake air flow alone.

This was achieved by means of the abovementioned electronic power plant, which is set to regulate the symmetry of the impulses sent to the injector on the basis of a signal that is proportional precisely to the intake-air flow.

This signal is furnished by a transducer sensitive to the vacuum Δp (relative to atmospheric pressure) detected in the throat of the venturi placed in the duct upstream from the carburetor; this vacuum is connected with the velocity of the fluid, and therefore, with the physical conditions of this fluid known, with its flow.

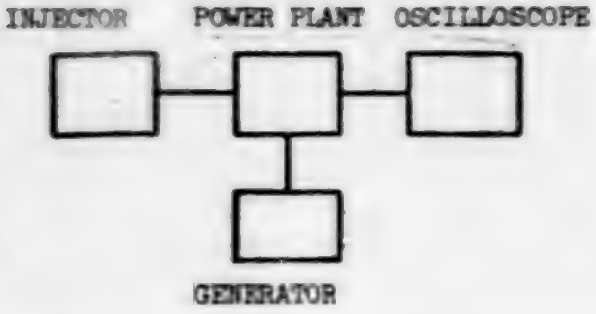


Figure 13. Apparatus for setting the electroinjector

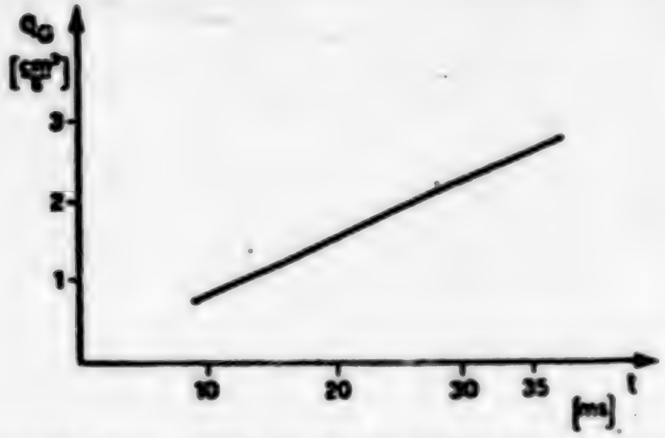


Figure 14. Gas-oil flows with variation of electroinjector opening time

To set the system, the following procedure was carried out.

The intake air flow in function of the Δp was determined; calculating the stoichiometric air/gas-oil ration A/F (equal to 14.4), and fixing the degree of richness of the mixture[3] with which it is desired to operate ($\phi = 1.1$), one arrives at the ratio A/F (equal to 15.8) to be achieved. From this follows the relation between fuel flow and Δp:

$$qG = 9.8 \cdot 10^{-1} \ (\Delta p)^{1/2} \ [cm^3/s];$$

This relation is given in the Figure 12 diagram.

On the other hand, the law of variation of the gas-oil flow in function of the opening times of the electroinjector (Figure 14) was arrived at experimentally.

The times were taken by oscilloscope, and the flows by flowmeter and chronometer.

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[3] Defined as the ratio between the effective mixture ratio and the stoichiometric ratio.

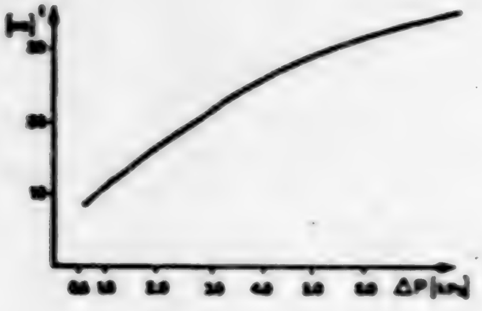

Figure 15. Curve of optimum opening times in function of Δp

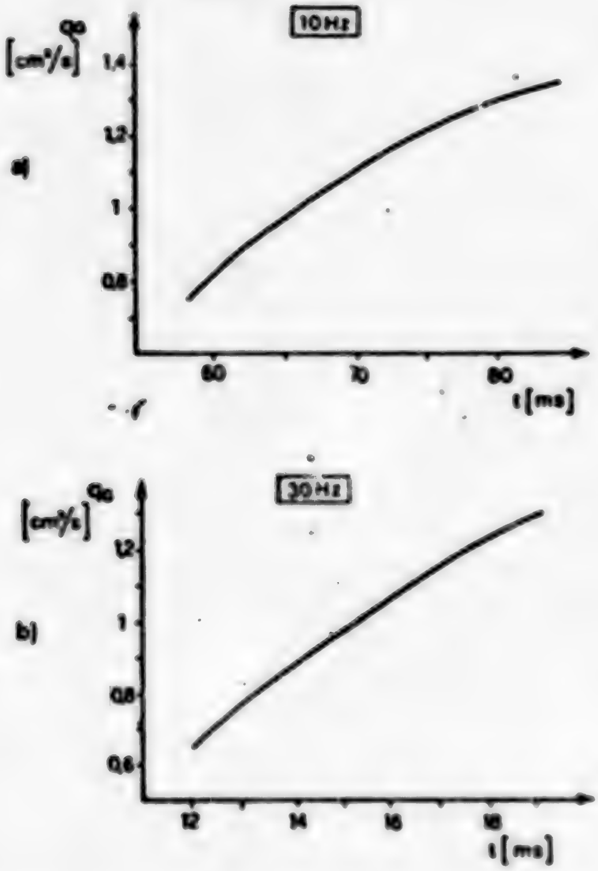

Figure 16. Curves observed for gas-oil flow with variation of electro-injector opening times

(a) power-supply frequency = 10 Hz
(b) power-supply frequency = 30 Hz

The relation between the Δp and the corresponding injector opening time was obtained by comparison between the two graphs, and the electronic power plant was set on the basis of this relation.

The setting of the manual regulation system was done by acting directly on the symmetry of the rectangular-wave generator, which, through the power plant, determines the opening of the electroinjector.

The curves which link the flows delivered by the injector at its opening times were determined experimentally for two different power-supply frequencies (Figure 16, a and b).

6. Measurement Apparatus

The measurements planned for the first phase of the investigation were essentially those of temperature, power, and fuel consumption.

Temperature Measurement--These measurements were made for the exhaust gases (at the entry and exit points in their circuit in the exchanger) and for the fuel (at the exit from the exchanger).

Ferroconstantan thermocouples inserted at the various measurement points were used. The output voltages were read by means of a digital voltmeter, and screening had to be provided to eliminate disturbances due to the electrical installation.

Power Measurements--These were done by means of a Schenck Ul - 16 hr parasite-current hydraulic brake with one-way rotation.

Consumption Measurements--Naturally, these were done for both gasoline and gas-oil operation.

In the former case, in accordance with conventional procedure, flowmeter and chronometer were used, while gas-oil consumption was deduced indirectly on the basis of the setting tables, as stated.

7. Experimental Results

The first series of tests--comprising the recording of the performance-characteristic curves and the pollution rate--were carried out on the engine in its stock version--running, therefore, on gasoline. Analogous observations were then made on the modified installation, still running on gasoline.

Practically no variation was encountered between the two cases, and this therefore indicates that the introduction of the circuits for the modified installation does not in itself cause appreciable reductions in performance, particularly in terms of load losses.

The set of data obtained will permit, as the investigation continues, a qualitative and quantitative comparison between the overall performance characteristics of the engine on gasoline and, in the modified version, on gas-oil.

The first operating tests of the installation on gas-oil were then conducted. It will be recalled that they had a twofold purpose:

—to demonstrate the possibility of regular functioning of the engine;

--to obtain all possible indications for eventual modifications of the installation in order to initiate the systematic tests planned for the parametric investigation.

After considerable difficulties in adjustment of the installation were overcome and the best overall working conditions were obtained, the tests, carried out by the methodology described above, produced a positive result: the engine functioned in a regular manner with gas-oil, albeit within a limited working range.

In some cases, spark advance was put in the optimum position for running on gasoline (position 1), and in other cases it was retarded a few degrees (4° to 6°) (position 2), so as to raise the knock threshold.

In a few tests, 20-percent acetone, with antiknock effect, was added to the gas-oil. The exchanger was always supplied with the entire flow of exhaust gases.

Tables II, III, IV and V summarize the results recorded during the tests, and for comparison, the results of the corresponding operation on gasoline.

Some further experimental observations are:

(1) smokiness proved sufficiently contained during the regular-functioning phases,while it appeared very abundant, and of light color, during the defective-functioning phases with strong knock;

(2) the carbon deposits noted inside the exchanger did not seem excessive;

(3) after the tests, the spark plugs always proved dry and free of fouling;

(4) the temperature of the gas-oil at the exit from the exchanger was 300° C. It was deduced from this that the maximum temperature reached by the fuel must be around several tens of degrees higher than this.

8. Considerations on the Results Obtained

The results reported represent the collection of a not very large number of data which taken all together do not furnish, and are not intended to furnish, a systematic framework permitting comparison of performance characteristics.

Table II. Data for Tests Carried Out with Gas-oil with Additive and Advance in Position 1

Engine Speed (RPM)	Braking Load (kg)	Power (kW)	Specific Consumption (g/kWh)	
			Gas-oil with additive	Gasoline
4,500	1.0	3.3	883	709
4,300	1.1	3.5	833	661
4,000	1.4	4.1	697	590
3,600	1.6	4.3	678	526

Voluminal mass of gas-oil with additive: 810 (g/dm^3)
Voluminal mass of gasoline: 730 (g/dm^3)

Table III. Data for Tests Carried Out with Gas-oil with Additive and Advance in Position 2

Engine Speed (RPM)	Braking Load (kg)	Power (kW)	Specific Consumption (g/kWh)	
			Gas-oil with additive	Gasoline
3,900	1.4	4.1	654	583
3,850	1.4	3.9	560	546
3,800	1.4	3.9	747	546
3,800	1.6	4.5	486	543
3,700	1.5	4.0	729	565
3,500	1.2	3.1	940	661

Voluminal mass of gas-oil with additive: 810 (g/dm^3)
Voluminal mass of gasoline: 730 (g/dm^3)

Table IV. Data for Tests Carried Out with Gas-oil Fueling and Advance in Position 1

Engine Speed (RPM)	Braking Load (kg)	Power (kW)	Specific Consumption (g/kWh)	
			Gas-oil	Gasoline
4,000	1.4	4.1	685	500
4,000	2.0	5.9	506	445
3,600	2.4	6.4	630	427

Voluminal mass of gas-oil: 830 g/dm^3)
Voluminal mass of gasoline: 730 (g/dm^3)

Table V. Data for Tests Carried Out with Gas-oil Fueling and Advance in Position 2

Engine Speed (RPM)	Braking Load (kg)	Power (kW)	Specific Consumption (g/kWh) Gas-oil	Specific Consumption (g/kWh) Gasoline
4,250	1.2	3.7	807	646
4,100	1.4	4.2	711	581
4,000	1.5	4.6	565	548
3,800	1.6	4.5	464	473
3,700	1.5	4.0	747	565

Voluminal mass of gas-oil: 830 (g/dm^3)
Voluminal mass of gasoline: 730 (g/dm^3)

Nevertheless, even with all the reservations stated, the fact that satisfactory functioning of the installation was achieved demonstrates substantially the validity of the idea proposed. What is more, the level of the power and specific-consumption characteristics are encouraging in their comparison with those delivered by the engine in stock condition; and this certainly seems to be one of the most important and indicative aspects for future research.

On the other hand, the principal reservations that can be stated in the present state of the research appear to be the following.

The engine functioned in too narrow a range of engine speeds, a range limited, at the lower end, by the knock threshold--knock, in this first phase, being detected exclusively by direct auscultation. Knock generally occurred below 3,000 RPM, and even in the proximity of this lower limit, the engine already show a typically rough running. On the other hand, the condition of the spark plugs leads one to believe that in the normal operating range (between 3,000 and 5,000 RPM), combustion was good.

In this regard, it was observed that the use of acetone mixed with the gas-oil did not produce any appreciable result.

It should be noted, however, that the gas-oil used was that commonly used in diesel engines for automotive transport. This fuel is produced by standards aimed at obtaining the greatest ignitability, either by admixture of appropriate hydrocarbons or by addition of detonation boosters.

The maximum temperature reached by the gas-oil in the exchanger is presumably less than that necessary for complete distillation of it (370° C).

Finally, spark advance was reduced in a limited degree.

9. New Program of Investigation

The indications that emerged during the first phase of the research suggested a series of modifications to be made on the installation as presently prepared. It appears advisable, in view of the positive results from the investigation so far, to initiate the second phase and the parametric analysis that it involves after a series of modifications of the installation, which are in progress and which we summarize here.

One special requirement is to facilitate to the maximum possible the completion of the thermochemical process inside the reactor and obtain products that are volatile and for the most part aeriform.

It is intended to take several approaches to this goal. They can be summarily characterized as, on the one hand, modifications to affect the temperature and pressure of the gas-oil in the exchanger, and on the other hand, modifications for catalytic effect.

As regards the temperature of the gas-oil, it is intended to work with two guidelines:

(a) improvement of the performance characteristics of the reactor, in terms of heat exchange, both by increasing the surface areas and by choosing materials with better coefficient of exchange, and finally, by increasing the insulation;

(b) supplementary injection of air into the exchanger, in quantities and in ways to be checked out experimentally. The purpose of this is to bring about combustion of a fraction of the gas-oil flow which should raise the mean temperature of all the fuel going through to above 800° C; among other things, the carbon particles present are burned at this temperature, with consequent cleaning of the gas flow going into the cylinder [6, 7].

The other energy advantages achievable are obvious. On the other hand, it has already appeared necessary to focus attention on the phenomena that occur inside the reactor; therefore, several measurement points have been created inside it for pinpoint recording of the gas-oil temperature. An analyzer of the composition of the mixture of the hydrocarbons exiting from the exchanger itself is also being inserted, with a shunt to the tube downstream from the exchanger.

It is intended to work on the pressure of the gas-oil in the thermal reactor by insertion of a control valve downstream from the reactor. An improvement in the reactor's performance characteristics with increase in pressure inside it is foreseeable.[4]

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[4] It is hardly necessary to stress the fact that for both types of modification referred to, the advantages and disadvantages resulting for the engines overall performance characteristics will be verified parametrically.

A catalytic modification to assist the thermal reactor is not beyond the scope of the investigation, despite the complication that it would cause, as well as the necessity of working out its durations, in addition to the positive effects.

Another aspect of great interest to be investigated attentively is the engine's behavior vis-a-vis pollution. Modifications for partial recirculation of the exhaust gases are not out of the question; neither is variation of the engine's timing so as to check its influence on the composition of the exhaust gases.

With regard to knock phenomena also, it will be recalled that proper timing --especially with verification of the effect of different advances on ignition--can prove decisive.

In this regard, it should also be emphasized that the investigationis equipment will necessarily include accelerometers capable of detecting the beginning of knock, as well as its intensity, rapidly and precisely.

With regard to both the problems of cracking and those of pollution, it will be necessary to conduct an investigation aimed at evaluating the behavior of the apparatus with different fuels in relation both to the influence of their basic composition and to the influence of any additives in them. In this regard it can be anticipated that in addition to different types of gas-oil, fuels of a different nature, such as kerosene and other hydrocarbon mixtures, will be tested.

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